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Tech Notes

December 1989

PB89-925912

Technology fact sheets from Federal laboratories

NTIS

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
Center for the Utilization of Federal Technology

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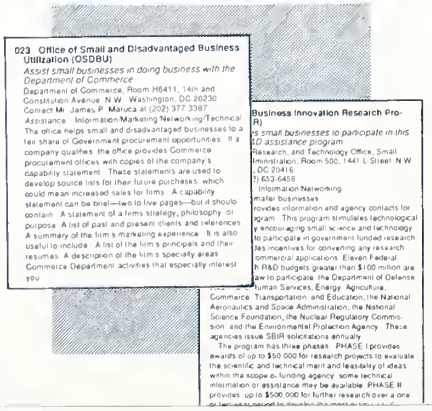
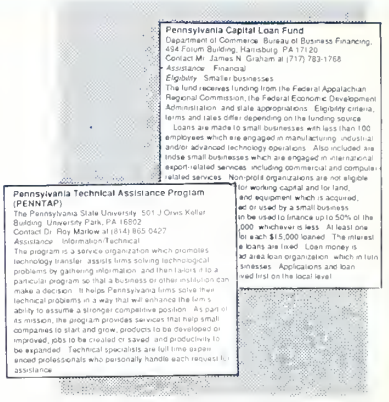
Federal Offices Want to Work with You

The 180 Federal entries selected for inclusion are arranged by agency. Discover sources of help in exporting, patent licensing, procurement, locating wage information, obtaining loan guarantees, finding marketing information, plus much more. A handy index lets you quickly locate just the Federal resources you need.


023 Office of Small and Disadvantaged Business Utilization (OSDBU)
Assist small businesses in doing business with the Department of Commerce
Department of Commerce, Room H6411, 14th and Constitution Avenue, N.W., Washington, DC 20230
Contact Mr. James P. Maruca at (202) 377-3387
Assistance: Information/Marketing/Networking/Technical
The office helps small and disadvantaged businesses to a fair share of Government procurement opportunities. If a company qualifies, the office provides Commerce procurement offices with copies of the company's capability statement. These statements are used to develop source lists for their future purchases, which could mean increased sales for firms. A capability statement can be brief—two to five pages—but it should contain: A statement of a firms strategy, philosophy, or purpose. A list of past and present clients and references. A summary of the firm s marketing experience. It is also useful to include: A list of the firm s principals and their resumes. A description of the firm s specialty areas. Commerce Department activities that especially interest you.

Business Innovation Research Pro-
R)
s small businesses to participate in this D assistance program
Research, and Technology Office, Small
ministration, Room 500, 1441 L Street N.W.
, DC 20416
) 653-6458
Information/Networking
maller businesses
rovides information and agency contacts for
gram. This program stimulates technological
y encouraging small science and technology
to participate in government-funded research
ies incentives for converting any research
ommercial applications. Eleven Federal
h R&D budgets greater than $100 million are
aw to participate: the Department of Defense
uman Services, Energy, Agriculture,
Commerce, Transportation and Education, the National
Aeronautics and Space Administration, the National
Science Foundation, the Nuclear Regulatory Commission, and the Environmental Protection Agency. These
agencies issue SBIR solicitations annually.
The program has three phases. PHASE I provides
awards of up to $50,000 for research projects to evaluate
the scientific and technical merit and feasibility of ideas
within the scope of funding agency; some technical
information or assistance may be available. PHASE II
provides up to $500,000 for further research over a one


Pennsylvania Capital Loan Fund
Department of Commerce, Bureau of Business Financing, 484 Forum Building, Harrisburg, PA 17120
Contact Mr. James N. Graham at (717) 783-1768
Assistance: Financial
Eligibility: Smaller businesses
The fund receives funding from the Federal Appalachian Regional Commission, the Federal Economic Development Administration, and state appropriations. Eligibility criteria, terms and rates offer depending on the funding source.
Loans are made to small businesses with less than 100 employees which are engaged in manufacturing, industrial and/or advanced technology operations. Also included are those small businesses which are engaged in international export-related services, including commercial and computer-related services. Non-profit organizations are not eligible.
for working capital and for land,
and equipment which is acquired,
ed or used by a small business
n be used to finance up to 50% of the
,000, whichever is less. At least one
lot each $15,000 loaned. The interest
e loans are fixed. Loan money is
ed area loan organization, which in turn
sinesses. Applications and loan
wed first on the local level.

Pennsylvania Technical Assistance Program (PENNTAP)
The Pennsylvania State University, 501 J. Orvis Keller Building, University Park, PA 16802
Contact Dr. Roy Marlow at (814) 865-0427
Assistance: Information/Technical
The program is a service organization which promotes technology transfer, assists firms solving technological problems by gathering information, and then tailors it to a particular program so that a business or other institution can make a decision. It helps Pennsylvania firms solve their technical problems in a way that will enhance the firm s ability to assume a stronger competitive position. As part of its mission, the program provides services that help small companies to start and grow, products to be developed or improved, jobs to be created or saved, and productivity to be expanded. Technical specialists are full time experienced professionals who personally handle each request for assistance.

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U.S. DEPARTMENT OF COMMERCE
Springfield, VA 22161.

Tech Notes

Highlighting Selected U.S. Government Technology & Resources

December 1989

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PENNSYLVANIA STATE UNIVERSITY

DEC 29 1989

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Published monthly by the National Technical Information Service (NTIS), Tech Notes bring together individual one- to two-page fact sheets prepared by Federal agencies, their laboratories, or contractors. These fact sheets highlight current Federal technology determined to have commercial or practical application. Topics cover new processes, materials, techniques, software, instrumentation, and resources.

Some of the current sources are the Department of the Navy, Department of the Army, NASA, Department of Energy, Environmental Protection Agency, Department of the Interior, and the Department of Agriculture.

Special assistance is provided by the Federal Laboratory Consortium.

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How to Use Tech Notes

Every Tech Notes fact sheet lists a source for additional information. The source of this information may be a special support package from the originating agency, a personal contact, a licensing opportunity, or a backup report available from NTIS.

Each fact sheet also is perforated to allow for easy removal for those subscribers who may wish to keep a special fact sheet file or route to others in their organization

Sources of Further Backup Information

Below are two representative examples of how each Tech Note fact sheet provides you with a source of further information. In most cases, this information is provided directly by the agency or its laboratory.

However, there are cases where NTIS is the source for backup documentation. In these cases, use the order form at the end.

Examples:

significant distance from the endwalls. Therefore, a radial variation in efficiency should be used when designing small stators.
Project Officer Jeffrey E. Haas
(216) 433-4000.

FOR ADDITIONAL INFORMATION

You can learn more about this technology by ordering the NTIS report(s):
Cold-Air Performance of Compressor Drive Turbine
Order number: AD-A101066/NAA
Price code: A02
Order from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

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- Agency contact who can supplement the information contained in the backup report.
- NTIS Order Number*
- NTIS Price Code*

* See the order form and price code table at the end of the issue.

Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN

FOR ADDITIONAL INFORMATION

Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

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- Agency reference number
- Source of more information about the technology described in the fact sheet
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1010 Image-Enhancement Aid for the Partially Sighted—Digital filtering would enhance the ability to read and to recognize objects.

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1013 Asymmetrical SRAM Cells for Radiation Tests—Features of circuits are altered to increase or decrease sensitivity to radiation. (Licensing Opportunity)

1014 Counterrotator and Correlator for GPS Receivers—All-digital design provides high accuracy and reduces cost. (Licensing Opportunity)

1015 High-Performance Power-Semiconductor Packages—A diode and a transistor satisfy stringent design criteria.

1016 Chip Advancer for GPS Receiver—Instrumental errors can be made negligible. (Licensing Opportunity)

1017 Monolithic III-V/Silicon Spatial Light Modulator—A silicon-based version provides for a choice of auxiliary on-chip circuitry. (Licensing Opportunity)

1018 Process for Patterning Dispenser-Cathode Surfaces—Microfabrication techniques increase uniformity.

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1044 Fluidized-Bed Reactor with Zone Heating—Deposition of silicon on the wall is suppressed.

1045 Improved Flow-Controlling Vortex Generator—Symmetrical tangential streams control flow of radial primary streams. (Licensing Opportunity)

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1058 Off-Line Programming System Improves Safety and Economy

1059 Inversion of Jacobian Matrix for Robot Manipulators—A closed-form transformation from task space to joint space is computed efficiently.

1060 Making Multicore, Multishell Microspheres—Multiple streams of fluids would be combined to produce various structures. (Licensing Opportunity)

1061 Structurally-Tailorable, Nonlinear, Snap-Through Spring—An abrupt change in load/deflection response is controllable and predictable. (Licensing Opportunity)

Other Items of Interest

1018 Process for Patterning Dispenser-Cathode Surfaces—Microfabrication techniques increase uniformity.

1025 Achromatical Optical Correlator—The signal-to-noise ratio should exceed that of a monochromatic correlator.

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Other Items of Interest

1032 Equation Developed for Predicting Steels in Fire

1044 Fluidized-Bed Reactor with Zone Heating—Deposition of silicon on the wall is suppressed.

1060 Making Multicore, Multishell Microspheres—Multiple streams of fluids would be combined to produce various structures. (Licensing Opportunity)

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1010 Image-Enhancement Aid for the Partially Sighted—Digital filtering would enhance the ability to read and to recognize objects.

1046 "Hazard I" Released to Help Reduce Fire Deaths and Costs

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1089 Enzyme Work Increases Industry Profits

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1092 Automated Hot-Cell Titration System

1093 Review of Current Methods for Measuring Particulate Matter Including Condensables from Stationary Sources

1094 Long-Wavelength Infrared Detector—Intersubband absorption in coupled quantum wells would enable detection at wavelengths from 10 to 100μm. (Licensing Opportunity)

1095 Making Durable Specimens for Electron Microscopy—Consistent metal-oxide cross sections are prepared quickly.

1096 Measuring Transmission Efficiencies of Mass Spectrometers—Coincidence counts would yield absolute efficiencies.

Other Items of Interest

1030 Choosing Compositions of Electrocatalysts—The best alloys for fuel cells and batteries can be determined from thermodynamical considerations. (Licensing Opportunity)

1055 Chemiluminescent Light Generating

1056 New Material can Help Gauge Sulfur Emissions

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1005 Predicting Cattle Parasite Numbers

Department of Energy

Technology Application

Solar Energy Research Institute

Enhanced Process Increases Ethanol Yield

SERI researchers are improving a method originally developed by Gulf Oil Co. and Japanese scientists to dramatically enhance the conversion of biomass to ethanol, a clean-burning liquid transportation fuel.

In the method, called simultaneous saccharification and fermentation (SSF), fungus-derived enzymes convert wood cellulose into glucose, which is then fermented into ethanol by yeast. SERI researchers have identified enzyme and yeast combinations that speed conversion time from 14 days to as few as 3 days. The special combinations also increase yields by as much as 25%, so that 90%-95% of the cellulose can now be converted into ethanol.

A bench-scale fermenter agitates biomass with selected yeast and enzyme combinations for improved ethanol yields.

Research is under way to optimize SSF for different types of biomass, including hardwoods, grasses, and woody wastes. For example, researchers found that a mixed yeast culture of *Brettanomyces clausenii* and *Saccharomyces cerivisiae* will rapidly convert pretreated wheat straw and poplar hardwood without the economically prohibitive enzyme levels required by single yeasts.

SERI research is expected to reduce ethanol costs to less than $0.60 a gallon, making this renewable fuel competitive with gasoline.

For Additional Information:

Charlie Wyman
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401-3393
(303) 231-1753

Refer to Volume XI, Number 2/TN

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Licensing Opportunity

Inhibiting Nitrogen Fertilizer Loss

A new way to spoon-feed nitrogen fertilizer to plants has been developed by an Agricultural Research Service chemist.

Arvin R. Mosier says about 10 to 40 percent of the nitrogen fertilizer that farmers put on their crops escapes into the air or is carried by water below the reach of plant roots.

In North America, this loss amounts to as much as 2 million tons annually.

The loss occurs during a natural chemical process that breaks down nitrogen fertilizer into forms plants can use. Unfortunately, the process may continue faster than plants can consume its output.

Mosier invented a way to inhibit this natural process by coating calcium carbide crystals with shellac. Applied with fertilizer, the calcium carbide slowly reacts with moisture in the soil to produce acetylene. The acetylene stops the nitrification process.

"When I started my studies, I was only looking for some way to stop nitrification during laboratory studies. But after considerable tinkering, it began to look like it would work for large-scale field applications," says Mosier. He is at ARS' Soil-Plant Nutrient Research unit, Fort Collins, Colorado. Nimai K. Banerjee, a chemist from the Indian Agricultural Research Institute in New Delhi, cooperated on this research.

Key to Mosier's finding was his knowledge of how turn-of-the-century miners' hat lamps worked. Water slowly dripping onto calcium carbide caused a chemical reaction that produced acetylene, a flammable gas that in turn lit the lamps.

Mosier's challenge was to invent a way to tame this natural chemical reaction. There was no danger of fields catching on fire if he merely applied the calcium carbide, but uncoated pellets would be used up in a few hours.

His best solution for slowing this reaction was to encapsulate the calcium carbide particles with shellac. This keeps acetylene production active for 2 to 3 weeks.

Preliminary studies suggest an application of about 20 pounds per acre with the cost of the inhibitor running about one-tenth the value of the fertilizer that otherwise would be lost.

Other nitrification inhibitors are commercially available, but they don't work on flooded fields or in soils with high organic matter.

Technical information is available from Arvin R. Mosier, USDA-ARS, Soil-Plant Nutrient Research Unit, Fort Collins, CO 80522. (303) 482-5733. U.S. Patent Application Serial Number 07/229,386, "Encapsulated Calcium Carbide as a Nitrification Inhibitor." ◆

FOR ADDITIONAL INFORMATION: Inquiries concerning rights for commercial use of this invention should be addressed to: Office of Federal Patent Licensing, Center for the Utilization of Federal Technology, Room 304, NTIS, Springfield, VA 22161; (703)487-4738. Refer to Patent Application 07/229, 386/TN

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Odorless, Lasting Protection for Wool

A new wool protectant developed by an ARS scientist protects wool garments from moths and beetles longer than moth balls and doesn't leave an odor.

The protectant is made from avermectin, an anti-parasitic agent produced by a soil fungus known as *Streptomyces avermitilis*. Tests have shown that the avermectin protectant withstands moth and beetle damage for at least 5 years in a single application.

The new wool protectant has also survived washing, dry cleaning, and excessive heat and light tests for durability. Avermectin was originally developed as a medicine to prevent internal parasites in animals. It kills webbing clothes moth and black carpet beetle larvae, while repelling furniture carpet beetle larvae—the primary enemies of wool clothing.

Roy E. Bry is in USDA-ARS Environmental and Special Problems Research, P.O. 22909, Savannah, GA 31403(912) 233-7981. ◆

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Licensing Opportunity

Perfume Fruit Flies Just Can't Resist

Vulnerable vegetable fields in California, Florida, Texas, Arizona and other Sun Belt states have a new early-warning option in case of attack by the destructive Malaysian fruit fly.

ARS scientists have found a potent new lure that males of that insect species just can't resist. The powerful compounds could be used to detect invading fruit flies and monitor their whereabouts.

Known to chemists as "cyclohexyl and cyclohexenyl aliphatic alcohols and ketones," the compounds occur in some plants. Makers of soaps and perfumes use the ketones to give a pleasing, violetlike fragrance to their products.

ARS research chemists Terrence P. McGovern, Beltsville, Maryland, Robert A. Flath at Albany, California, and Roy T. Cunningham, Hilo, Hawaii, have named their new attractant "Latilure," after the insect's scientific name, *Dacus latifrons*.

The fly, cousin to the notorious Mediterranean fruit fly, or medfly, is about one-third the size of a common house fly, with a rusty brown abdomen and bright yellow stripes where its wings are attached.

It is a native of Taiwan, Thailand, Laos, and the Malay Peninsula. So far it has succeeded in settling in only one state—Hawaii. In 1983, it was first spied in a few small fields of chili peppers on the island of Oahu.

Agricultural officials in California were unsettled by the fly's proximity to their state's fields of tomato, eggplant, and bell pepper—all Malaysian fly favorites. So California funded much of the research that led to the attractant.

Crops are ruined when the female fly settles on ripening vegetables, then punctures the surface with her slender, tubelike ovipositor. Eggs that she pumps through the ovipositor develop inside the vegetable into tiny white maggots that make crops unsalable.

So far, the insect has made only two forays into California—both unsuccessful.

It was found among red peppers, okra pods, and eggplants hidden in the trunk of a car that a returning sailor had shipped to the mainland. Another time the fly turned up in a package of produce mailed—illegally—into this country. The new lure increases the odds that agricultural agents in California and elsewhere will be able to find such invader flies even faster in the future.

For technical information about this patentt,contact Terrence P. McGovern, USDA-ARS, Insect Chemical Ecology Laboratory, Room 8, Bldg. 010, BARC-West, Beltsville, MD 20705 (301) 344-2138. Patent No. 07/247,546, "Attractants for *Dacus latifrons*, the Malaysian Fruit Fly." ◆

GRANT UCHIDA

Latlure is a man-made attractant that has been developed for the Malaysian fruit fly, *Dacus latifrons*.

FOR ADDITIONAL INFORMATION: Inquiries concerning rights for commercial use of this invention should be addressed to: Office of Federal Patent Licensing, Center for the Utilization of Federal Technology, Room 304, NTIS, Springfield, VA 22161; (703)487-4783. Refer to Patent Application 07/247,546/TN.

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Predicting Cattle Parasite Numbers

Daniel Snyder isn't just hoping that his Holstein calves pick up plenty of internal parasites this spring and summer—he's *counting* on it.

Snyder is a microbiologist at the Agricultural Research Service's Animal Parasite Research Unit in Auburn, Alabama.

There he's riding herd on a project that could yield a computer model to help cattle producers predict how severe the parasite problem is likely to be on their pastures at specific times. Among the species under study are the brown stomach worm *(Ostertagia ostertagi);* the barberpole worm, *(Haemonchus placei);* and some of the small intestinal worms *(Cooperia).*

"We get calves that haven't been exposed to parasites, and we put them out on pastures where the infective stages of the parasites are occurring," explains Snyder. "We leave them there for 30 days, then take them off and examine them for parasites. Every month, we put out two new calves.

"From this, we can get information on the kinds and numbers of parasites on the pastures. We can also get an idea of whether there's a seasonal variation—for example, is there a higher prevalence of a certain type of parasite in the fall?"

The project was begun in August 1987 at Auburn but has grown to include study sites in central and northern Alabama and on the Gulf Coast, Snyder says.

"We want to develop the computer model using this information. Then we'll use the model to see if we can predict parasite development at different locations and times.

"This is aimed at giving the cattle producer an idea of what's out there. Hopefully, they can use this information in their management plans. For example, if they know parasites will be on the pastures in high numbers at a certain time, they won't put their cattle there then."

The model could prove useful to cattle producers in Georgia, North and South Carolina, Mississippi, Louisiana and Florida as well as Alabama, Snyder says.

"We hope to have a handle within 2 years on where the model's going—whether it could be used on the cattle rancher's own personal computer, or if it would be a matter of an Extension Service agent or a university's animal science department having it on hand to provide the answers," Snyder says.

Daniel E. Snyder is at the USDA-ARS Animal Parasite Research Unit, P.O. Box 952, Auburn, AL 36831 (205) 887-3741. ◆

Computers

Software

1006 TWIRE: A Test Program for VLF Airborne Transmissions

1007 Single-Board Microcontroller Suitable for Rapid Prototyping

1008 Design of Combined Stochastic Feedforward/Feedback Control—Methodology accommodates a variety of control structures and design techniques.

1009 Ideal Resampling of Discrete Sequences—Spectral information is preserved to the extent possible.

1010 Image-Enhancement Aid for the Partially Sighted—Digital filtering would enhance the ability to read and to recognize objects.

U.S. Navy Technology Application

TWIRE: A Test Program for VLF Airborne Transmissions

Previously VLF propagation code was developed for calculating VLF fields produced by antennas of arbitrary length, shape and elevation. The program was based on simple segmentation of the antenna with each segment acting as a short dipole. The field strength at any distance from the antenna was then calculated as the phasor sum of the contributions from each segment. To perform the calculations presented by Bickel et al (1971), the positions and orientations of the antenna segments had to be manually input to the propagation code along with the current moment for each segment. The latter required an assumed current amplitude and current distribution along the antenna. In particular, no rationale was used to relate current amplitude to radiated power. The latter is generally the quantity assumed in systems calculations.

The purpose of current work is to describe a computer program called TWIRE which combines several programs and facilitates calculations of the type made by Bickel et al (1971) and which uses as one of its fundamental inputs the power radiated by the antenna. Specifically, TWIRE combines the configuration code of NADC with a simple radiation resistance program (Pappert 1986) and fast mode conversion propagation code (Ferguson & Snyder, 1980). TWIRE also makes allowance for the counterpoise which is typically about an eighteenth of the rf wavelength (Fern 1986).

The NACD code calculated the steady state antenna configuration by assuming an aircraft executing a circular orbit at constant altitude and speed. The radiation resistance code assumes a sinusoidal current distribution along the antenna and is strictly valid for a flat infinitely conducting ground. Nevertheless, it is believed to be a reasonable approximation for high conductivity ground (e.g., seawater). Towline plus counterpoise is assumed to be one-half of the rf wavelength. Propagation in either laterally homogeneous or inhomogeneous environments is allowed for by the fast-mode conversion program.

The NADC program determines steady state configurations of the towline from force equations by an iteration procedure which uses as starting conditions the radius and altitude of the conical drogue at the bottom of the towline. To achieve convergence it is generally necessary to begin with good drogue starting conditions. That requirement, unfortunately, prevents full automation of TWIRE. An effective operating procedure is to determine starting conditions by running the NADC code separately for a set of operating conditions, and to then employ those starting conditions in TWIRE.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact R.A. Pappert, Naval Ocean Systems Center, Code 542, San Diego, CA 92152: (619)553-3069.

Oak Ridge National Laboratories

Single-Board Microcontroller Suitable for Rapid Prototyping

The National Association of Home Builders (NAHB) Smart House Project is a cooperative research and development effort involving American home builders and a number of major corporations. The purpose of the project is to incorporate current technology in the distribution and use of energy and communication services in the home. ORNL is contributing to the Smart House Project by providing technical advice and consulting services to NAHB in the areas of overall evaluation and design, project management, and development of facilities for use in design evaluation and system integration.

Certain parts of the designs now used for home electrical and gas-distribution systems are as much as 100 years old. In spite of the radical change in energy-use patterns (from primarily lighting to primarily heating and cooling use), the basic energy-distribution and control systems used in homes have not changed in several decades. As a result, the needs of modern homes are not being met. The Smart House Project will provide designs for intelligent control and coordination services among appliances and the devices used to control their operation.

The Smart House design must meet rigid

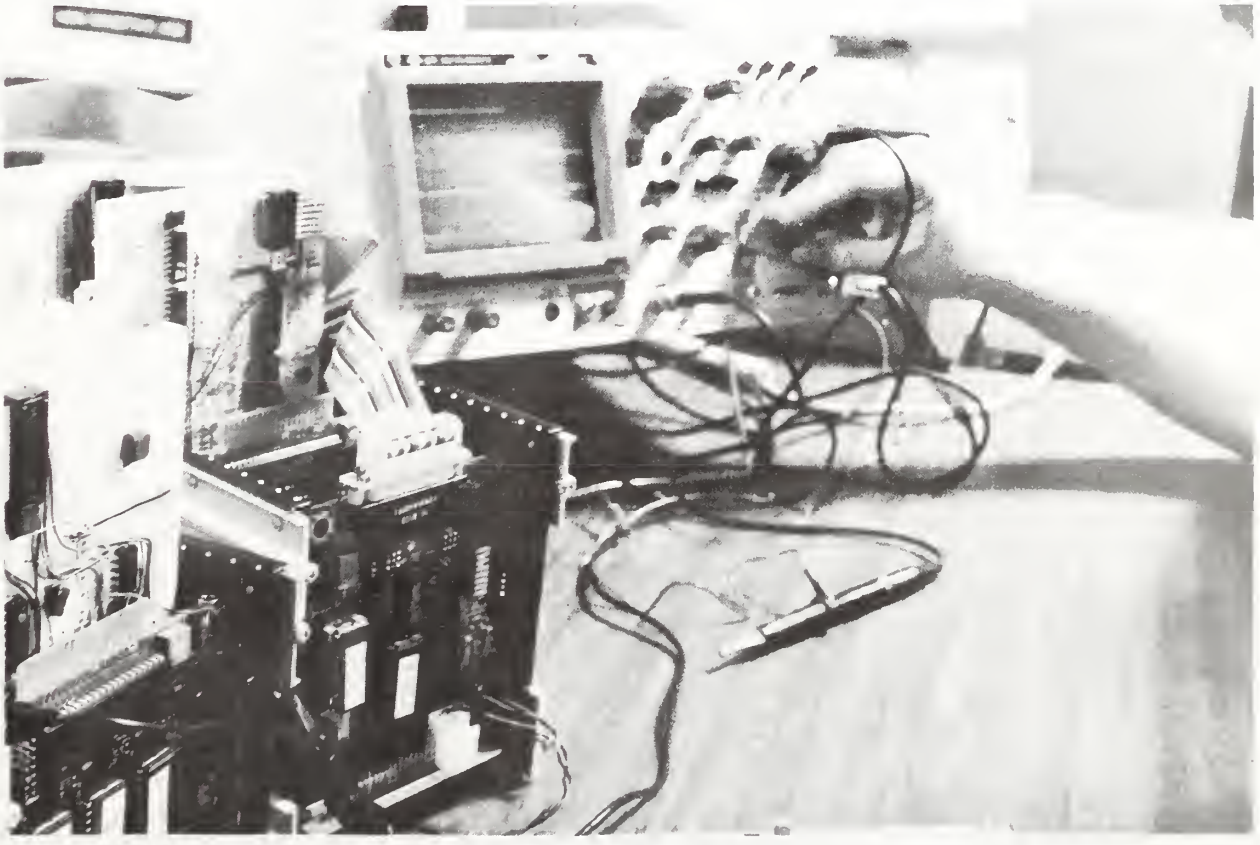

Fig. 1. Single-board microcontroller for use in developing and testing Smart House products.

requirements for reliability, installability, and maintainability. This design will also establish a new standard of safety for power distribution in the home, primarily by incorporating closed-loop control of electrical appliances. With this feature, branch circuits are de-energized except when power is necessary to operate appliances. To initiate the flow of power, the device controlling an appliance (such as the switch on a vacuum cleaner) must send an electronic message to the control for the circuit leading to the appliance. After the circuit is powered, the control for the circuit requires a continuing "nominal operation" signal from the appliance to maintain the supply of power.

Researchers in ORNL's Energy Division evaluated a commercially available, single-board microcontroller for use in developing and testing Smart House products (Fig. 1). Two ORNL reports, *Evaluation of a Single-Board Microcontroller Suitable for Rapid Prototyping,* and *Optimizing the Zilog Z8 FORTH Microcontroller for Rapid Prototyping,* concern criteria ORNL has developed for evaluating microcontrollers intended for use in rapid prototyping, the adaptation of a commercially available microcontroller to meet these requirements, and a summary evaluation of both the prototyping requirements and the performance of the candidate microcontroller.

Based on experience in laboratory development and testing for DOE conservation programs, ORNL presented requirements that should be met by a microcontroller suitable for rapid prototyping. A commercially available, FORTH-based microcontroller then was evaluated against these requirements. The study showed that a full-screen editor can be developed for the tested single-board microcontroller in about 40 h. Execution speed of a FORTH control program can range from 12 times slower to 3 times faster than IBM AT FORTH, depending on the degree of optimization of the microcontroller FORTH program. The report shows how Z8 FORTH-provided system primitives can be redefined to achieve fast execution speed. Also, ORNL devised a simple modification of Z8 FORTH to support multitasking. The microcontroller that was evaluated generally met rapid-prototyping requirements. The test resulted in concern about the readability of FORTH control programs, the execution speed of nonoptimized FORTH, and the need to augment the basic complement of FORTH words provided with the microcomputer

R. Edwards, *Evaluation of a Single-Board Microcontroller Suitable for Rapid Prototyping,* ORNL/TM-10361, Oak Ridge National Laboratory (February 1987).

R. Edwards, *Optimizing the Zilog Z8 FORTH Microcontroller for Rapid Prototyping,* ORNL/TM-10463, Oak Ridge National Laboratory (September 1987).

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Design of Combined Stochastic Feedforward/Feedback Control

Methodology accommodates a variety of control structures and design techniques.

A methodology for the design of combined stochastic feedforward/feedback control has been developed, and a digital automatic landing system has been designed by use of this approach. The main objective of a control law is to enable a plant to track a desired or commanded trajectory selected from a given class of trajectories as closely as possible in the presence of random and deterministic disturbances and despite uncertainties about the plant. The feedforward controller tries to track the desired or commanded trajectory, whereas the feedback controller tries to maintain the state of the plant near the desired trajectory. Modern control theory has concentrated more attention on the important feedback control problem, while the feedforward control problem has received less attention.

In the methodology for combined stochastic feedforward/feedback control, the main objectives of the feedforward and feedback control laws are seen clearly. The inclusion of error-integral feedback, dynamic compensation, rate-command control structure, and the like is an integral element of the methodology. Another advantage of the methodology is the flexibility to develop a variety of techniques for the design of feedback control with arbitrary structures to obtain the feedback controller: These include stochastic output feedback, multiconfiguration control, decentralized control, or frequency and classical control methods.

A specific incremental implementation is recommended for the combined feedforward/feedback controller. Some advantages of this digital implementation are simplicity, elimination of the need for trim values, and avoidance of such problems as integrator windup. The closed-loop eigenvalues obtained in this implementation contain the designed closed-loop eigenvalues that would result if an incremental implementation were not used. It has been shown that when using an incremental implementation, it is advantageous to design the controller with as many integrators as the number of controls. The use of fewer integrators results in marginally stable eigenvalues of unity, while the use of more integrators constrains the placement of eigenvalues.

A digital automatic landing system for the Advanced Transportation Operating System (ATOPS) research vehicle, a Boeing 737-100, has been designed by use of the stochastic-feedforward-controller and stochastic-output-feedback methodology. The control modes of the system include the capture and tracking of the localizer and glideslope, crab, decrab, and flare. By use of the recommended incremental implementation, the control laws have been simulated on a digital computer and connected with a nonlinear digital simulation of the aircraft and its systems.

This work was done by Nesim Halyo of Information and Control Systems, Inc., for **Langley Research Center**. *Further information may be found in NASA CR-4078 [N87-25806], Price Code: A07 "A Combined Stochastic Feedforward and Feedback Control Design Methadology with Application to Autoland Design."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LAR-13795/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Ideal Resampling of Discrete Sequences

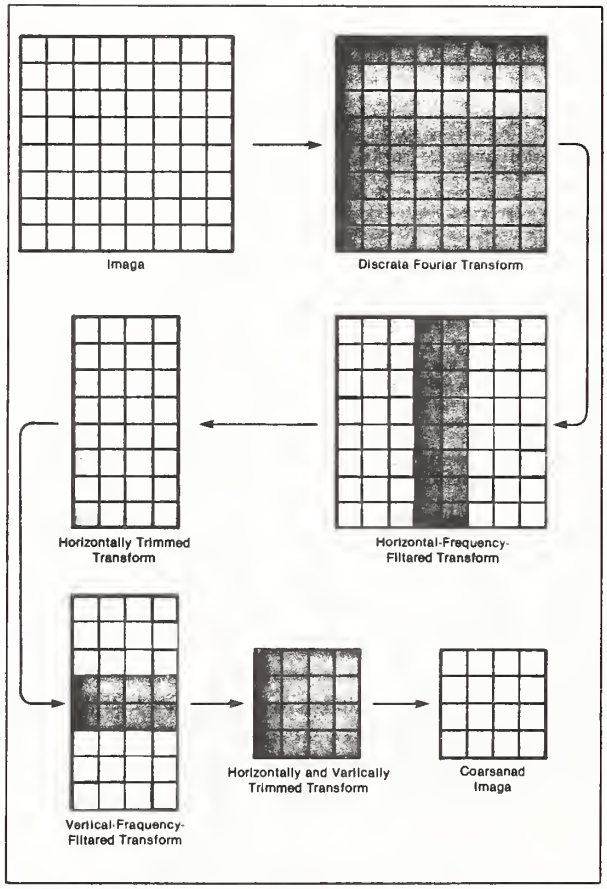
Spectral information is preserved to the extent possible.

A technique has been developed to shrink or expand a discrete input sequence of numbers into an output sequence in a manner that preserves the input spectrum up to the Nyquist limit of the smaller of the two sequences. In the case of expansion, the technique also prevents the introduction of spurious frequencies not present in the input. While the technique is applicable to many kinds of data sampled at regular intervals, it is particularly useful in the processing and enhancement of images, where the discrete sequences are spatially ordered sets of picture-element brightness values.

The problem is to change the input sequence of N numbers to an output sequence of M numbers. The first step of the solution is to take the discrete Fourier transform (DFT) of the input. The DFT is used to reconstruct a continuous, band-limited function containing the same spectrum as that of the input sequence. This is the function that one would observe upon low-pass filtering an input signal below the Nyquist frequency of the sequence (and taking half the amplitude at the Nyquist frequency) and is the function that yields the input sequence when sampled at the input times or positions.

The continuous function is low-pass filtered to eliminate frequencies (if any) above the Nyquist rate of an M-sample sequence. This can be done in the frequency domain by taking the product of the DFT and the filter frequency dependence, or in the time or space domain by convolution with a sinc function of frequency M. In the time or space domain, the filtered signal can be converted to the output sequence by sampling it at intervals of 1/M. Alternatively, the filtered DFT can be convolved with a pulse-train DFT, then inverted to the time or space domain to yield the output sequence.

A two-dimensional array of numbers (e.g., image data) is treated by applying the technique to the two-dimensional DFT's of the rows and columns of picture elements. Similarly, third-order and higher-order arrays are treated via the applicable multidimensional DFT's. The technique might be used, for example, to expand an image array, increasing the number of picture elements to smooth out the grainy appearance of a few large picture elements. Alternatively, it might be used to decrease the number of picture elements (see figure).



An **Image Is Coarsened** by resampling to reduce the number of picture elements while preserving as much as possible of the original image information.

If the third dimension of a three-dimensional array is time, the technique could be applied to create a slow-motion image sequence without the difficulty of recording rapidly, then playing back at low speed. The image would be recorded at the normal frame rate and played back at the lower frame rate. The technique would be used to generate intermediate images at small intervals between frames, thereby suppressing the appearance of jerky motion caused by the sudden jumps between frames at the low frame rate.

This work was done by Andrew B. Watson of **Ames Research Center**. *Further information may be found in NASA TM-88202 [N88-19100], Price Code: A03 "Ideal Shrinking and Expansion of Discrete Sequences."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11719/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Image-Enhancement Aid for the Partially Sighted

Digital filtering would enhance the ability to read and to recognize objects.

An experimental digital electronic image-processing system may eventually assist partially sighted people in reading and in recognizing objects or small visible features. The system is intended primarily to help individuals who have central vision losses such as age-related maculopathies. These disorders degrade the high resolution central vision, forcing one to rely on the lower resolution peripheral areas of the retinas to recognize patterns. It should be possible to construct a portable vision aid by combining miniature video equipment to observe the scene and display the images with very-large-scale integrated circuits to implement real-time digital image-data processing.

In effect, the system is digitally "fitted" to each eye. First, the patient's contrast-sensitivity function would be measured by asking the person to look at and detect patterns of various spatial frequencies and contrasts in a visual testing and training instrument. The contrast-sensitivity function maps out the range of one's visible spatial frequencies. Generally, the afflicted observers can see only low and intermediate spatial frequencies (below about 8 cycles per degree).

The clarity of the perceived image can be partly restored by enhancing those spatial-frequency components that are less visible to the afflicted than to a normal observer of the same age. A measure of the required enhancement as a function of spatial frequency is provided by the reciprocal of the afflicted observer's normalized contrast-sensitivity function (NCSF), which is the afflicted patient's contrast-sensitivity function divided by the contrast-sensitivity function of the normal observer. The reciprocal of the NCSF is limited to the spatial frequencies between the lowest and highest spatial frequencies visible to the afflicted observer.

The digital compensating filter derived from the NCSF is implemented as a transfer function that multiplies a fast Fourier transform of the scene in spatial-frequency space (see Figure 1). The individualized compensation filter that is marketed will be filtering in the spatial domain for fast, inexpensive image enhancement. The compensating filter includes a gain term that

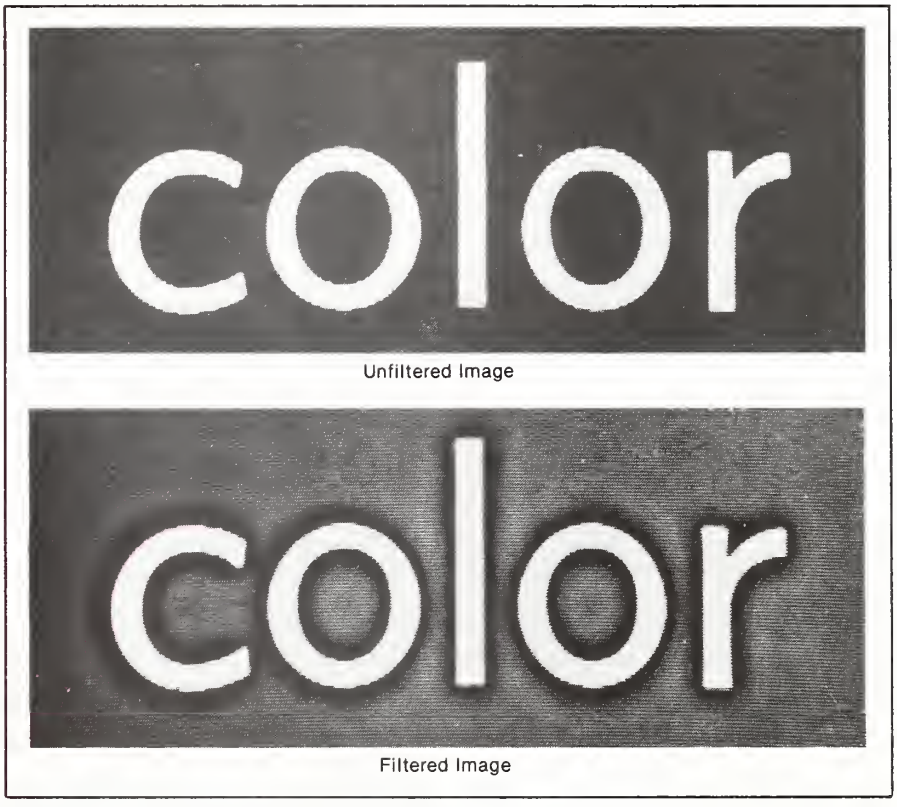

Figure 2. The **Filtered Image** of the word is more easily recognized by an afflicted observer than is the unfiltered image.

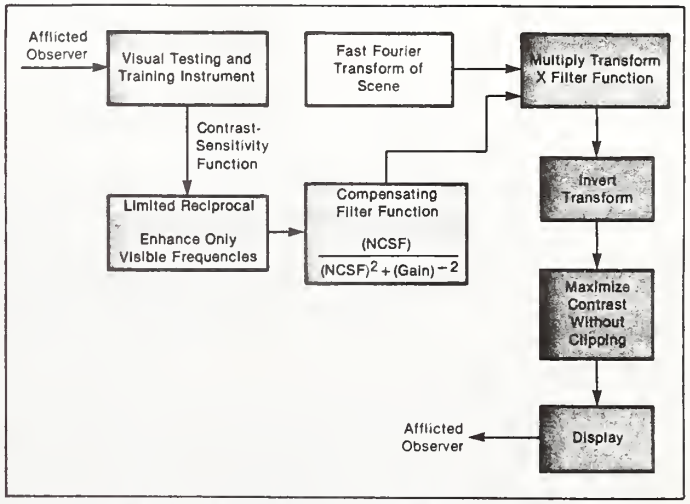

Figure 1. A **Digital Filter in the Spatial-Frequency Domain** is derived from the afflicted observer's normalized contrast-sensitivity function (NCSF) and used to enhance the spatial frequencies that appear less visible.

controls the compromise between enhancement of resolution and rejection of noise. The fast Fourier transform is then inverted, and the contrast of the resulting processed image (see Figure 2) is adjusted to prevent clipping at the bright and dark extremes of the scene.

An afflicted observer could view the scene through a magnifier to shift the spatial frequencies downward and thereby improve the perceived image. However, the less the magnification needed, the larger the scene that can be observed. Thus, one measure of the effectiveness of the new system is the amount of magnification required with and without it. In a series of tests, it was found that 27 to 70 percent more magnification was needed for the afflicted observers to recognize unfiltered words than to recognize filtered words.

This work was done by T. A. Lawton and D. B. Gennery of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell,
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Refer to NPO-17307/TN.

Electrotechnology

1011 Secure Indications and Warning Video Communications System

1012 Boundary-Value Problem for Magnetic-Cutoff Rigidities—Field equations can yield an overview of motions of many charged particles.

1013 Asymmetrical SRAM Cells for Radiation Tests—Features of circuits are altered to increase or decrease sensitivity to radiation. (Licensing Opportunity)

1014 Counterrotator and Correlator for GPS Receivers—All-digital design provides high accuracy and reduces cost. (Licensing Opportunity)

1015 High-Performance Power-Semiconductor Packages—A diode and a transistor satisfy stringent design criteria.

1016 Chip Advancer for GPS Receiver—Instrumental errors can be made negligible. (Licensing Opportunity)

1017 Monolithic III-V/Silicon Spatial Light Modulator—Provides for a choice of auxiliary on-chip circuitry. (Licensing Opportunity)

1018 Process for Patterning Dispenser-Cathode Surfaces—Microfabrication techniques increase uniformity.

1019 Stabilizing Semiconductor Devices with Hydrogen—Damage by radiation would be healed rapidly. (Licensing Opportunity)

1020 Ultra-Stable Superconducting-Maser Oscillator—Frequency fluctuations would be reduced to as little as 2×10^{-19}. (Licensing Opportunity)

Software

1021 Computer-Aided Engineering of Cabling—This program generates data sheets, drawings, and other information on electrical connections.

1022 Designing Corrector Optics—Image-spot radii can be reduced by factors ranging from 5 to 25.

Testing & Instrumentation

1023 Evaluation of High-Frequency Power Meters

1024 Automatic Parametric Testing of Integrated Circuits—A software system generates its own test instructions and teaches itself new tests.

1025 Achromatical Optical Correlator—The signal-to-noise ratio should exceed that of a monochromatic correlator.

Other Items of Interest

1026 Cascade Cell Sets Record Efficiency (Licensing Opportunity)

1027 Gravimetric Separation Technique

1028 Infiltration Reduction for Single-Family Houses

1091 Dynamic-Range Compression for Infrared Imagery—Photorefractive crystals covering detectors would prevent saturation.

Technology Application

Idaho National Engineering Laboratory

Secure Indications and Warning Video Communications System

The Secure Indications and Warning Video Communications System is a prototype, multimedia, secure communications system. It provides real-time full-motion video, freeze-frame video, full-duplex audio, graphics and digital-data communications to a selected number of intelligence indications and warning (I&W) canters within the Department of Defense (DOD). The prototype development includes design, integration and installation of local command networks that when linked together into a wide area network form a communications system that will enable remote interactive analysis and management of I&W situations and crises.

The SVCS integrates commercial off-the-shelf video and audio technology incorporating digital communications compression techniques, cryptographic devices, and highly user-friendly computer control. Each command network has been configured for the unique requirements of video, audio, data communications, image and display that fit into the normal working environment and operational process of their I&W center.

The open architecture of the SVCS provides a framework for the current flexibility and any future enchancements. The basic concepts incorporated in the architecture are compatibility with existing government video teleconferencing systems, tailoring to fit the continually changing working environment of the I&W centers, operational simplicity to eliminate special training and maintenance requirements, and expandibility to allow for future technology advancements. The subsystems that make up each SVCS installation include communications (T-1, RS449, RS232, baseband NTSC and RGB), video (studio quality), audio and computer control (MICROSOFT WINDOWS).

The SVCS is a prototype system that provides a model or pattern for future development. If the current growth is any indication of the future, the system will expand to a wide area network that will encompass the unified and specified (U&S) commands and other selected intelligence indications and warning centers.

Teleconferencing is only one function of SVCS, in addition, the system also provides for internal/ external briefings, demos, newscasts, etc. Unlike most commercial systems designed to fixed room configurations, SVCS will fit into existing I&W environments. The entire system is also designed to be operated within a security controlled facility with the intelligence analyst providing full operation of the system.

Applications include military installations; industrial power plants; monitoring activities at remote sites; basic communication between sites; maintenance operations.

FOR ADDITIONAL INFORMATION: Contact Jack G. Peterson, Idaho National Engineering Laboratory, P.O. Box 1625, Idaho Falls, Idaho 83415: (208)526-2893. Refer to DOE/INEL-048/TN.

NASA Tech Brief
National Aeronautics and Space Administration

NASA's Jet Propulsion Laboratory, Pasadena, California

Boundary-Value Problem for Magnetic-Cutoff Rigidities

Field equations can yield an overview of motions of many charged particles.

An alternative approach has been developed for the calculation of the magnetic cutoff rigidities of electrically-charged particles in a static magnetic field. In contrast with the conventional formulation, in which the trajectories of particles are traced by solution of the equations of motion, the new formulation involves a partial differential field equation that is treated as a boundary-value problem. In this approach, the tracing of trajectories is needed only to supply boundary conditions.

"Rigidity" is used here in the astrophysical sense meaning the ratio of momentum of a particle to its electrical charge. Typically, the rigidities of particles arriving at a given location from a given direction can be grouped into bands of rigidities, within which the particles cannot escape to infinity, and outside of or between which they can escape to infinity. "Cutoff rigidity" denotes the least upper bound or the greatest lower bound of such a band. Thus, the calculation of cutoff rigidities is important in such endeavors as estimating the degree to which magnetic fields could protect spacecraft from solar-flare particles, designing experiments in atomic physics, and extracting energy from nuclear-fusion reactions.

The mathematical development begins with the basic equation of motion of a relativistic charged particle in a magnetic field. The rigidity is substituted for the momentum in this equation to obtain a differential equation in terms of the rigidity, the magnetic field, and displacement along the trajectory. Another differential equation is introduced to express the constancy of rigidity along the trajectory. The foregoing equations are combined and manipulated to yield two alternate forms of the partial differential field equation for the cutoff rigidity:

$$\hat{\mathbf{P}}\cdot\nabla_x F + (\hat{\mathbf{P}}\times\mathbf{B})\cdot(P/F)\nabla_p F = 0$$

and

$$\hat{\mathbf{P}}\cdot[\nabla_x F + \mathbf{B}\times(P/F)\nabla_p F] = 0$$

where P is the rigidity (magnitude of the rigidity vector $P\hat{\mathbf{P}}$), $\hat{\mathbf{P}}$ is the unit vector tangent to the trajectory in the direction of the rigidity, F is the cutoff rigidity, ∇_x is the gradient operator in position space, ∇_P is the gradient operator in rigidity space, and $\mathbf{B}$ is the magnetic-flux-density vector.

Once the field equation is supplemented by boundary conditions, and subject to requirements of existence and uniqueness of solutions, a solution should be obtainable. When the magnetic field is axisymmetric (e.g., in a cylindrical solenoid or in a dipole approximation of the magnetic field of the Earth), the equations can be simplified considerably when one considers the generalized Stormer cutoff. It can be shown that the vertical cutoff, which is the generalized Stormer cutoff evaluated in a direction perpendicular to magnetic east, is constant on a magnetic-field line. This means that the cutoff can be evaluated at an arbitrary location by following the magnetic-field line that passes through that location until it intersects a surface on which the cutoff has been specified as a boundary conditon.

Analytic solutions for the cutoffs can be obtained for a large class of problems with axial symmetry. A procedure for finding the magnetic field that provides the best protection against charged particles, subject to a certain kind of constraint, has been derived. Each application of this procedure yields an inequality that can be used as an upper-bound estimate of the protection that can be provided by a given axially-symmetric magnetic field.

This work was done by Larry D. Edmonds of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17294/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Asymmetrical SRAM Cells for Radiation Tests

Features of circuits are altered to increase or decrease sensitivity to radiation.

The features of static random-access memory (SRAM) integrated circuits can be altered to increase or decrease the susceptibility of memory cells to single-event upsets — changes in logic states induced by impacts of energetic charged particles. The ability to do this is important for the design of radiation-detecting integrated circuits (deliberately made more sensitive to ionizing radiation) and "radiation-hardened" integrated circuits — those intended to be relatively invulnerable to intense radiation.

As the drain of a transistor is enlarged, it can intercept more radiation, thus becoming more susceptible to single-event upsets. However, the capacitance of the affected circuit node also increases, thus decreasing the change in drain voltage caused by the deposition of a given amount of charge from an impact, and this effect decreases the susceptibility to single-event upsets. Because these two competing effects occur to different degrees in different transistors of a memory cell, they can be traded off against each other. Selected areas of different transistors can be enlarged by different proportions that result in a specific overall increase or decrease in the susceptibility to single-event upsets.

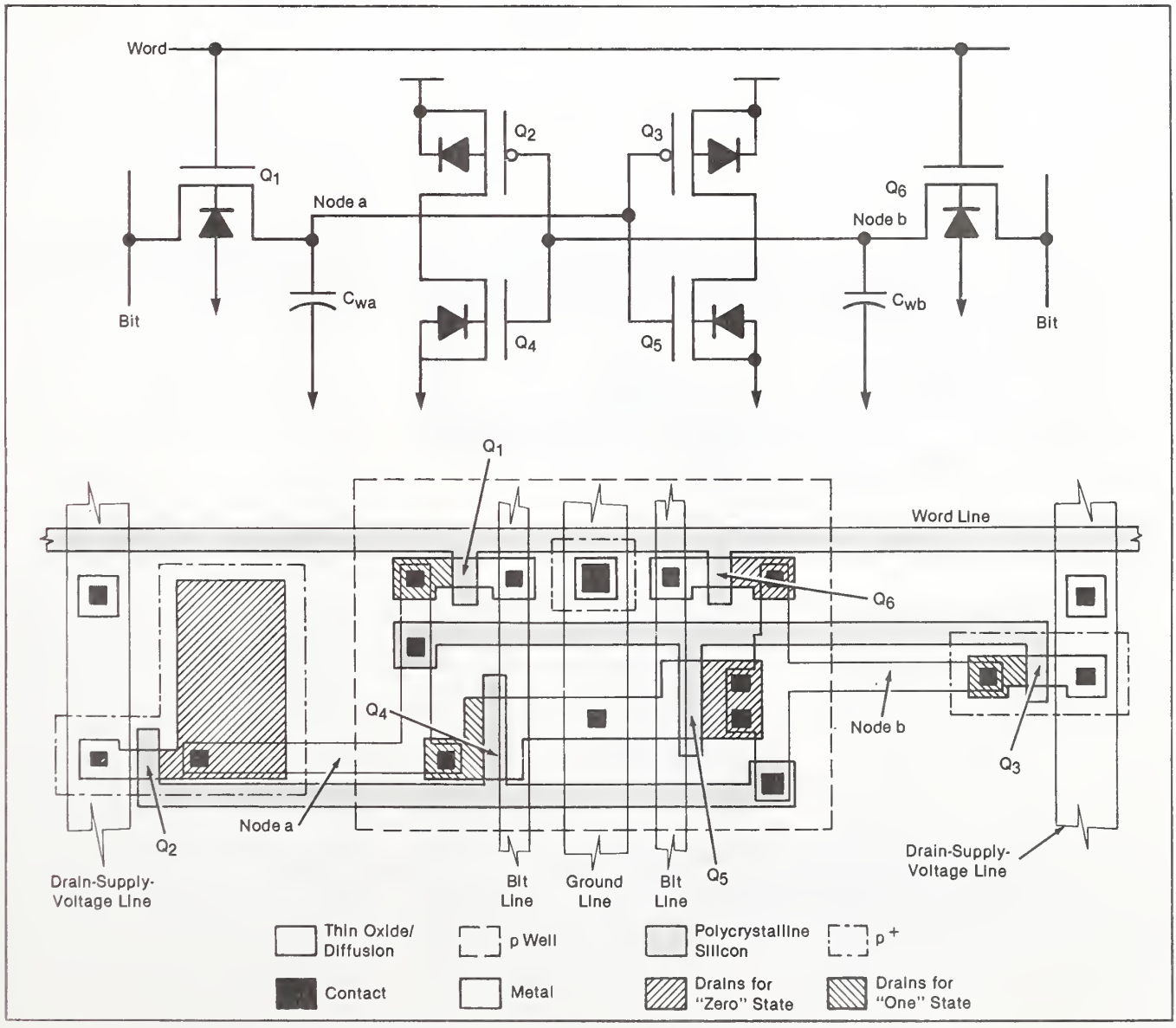

Figure 1. This **Six-Transistor SRAM Cell** was made in versions with different sizes of the areas sensitive to single-event upsets (cross hatched areas).

For example, in the SRAM cell of Figure 1, the rate of upsets can be increased by the use of asymmetrically enlarged drain regions in pullup transistor Q_2 and pulldown transistor Q_5. For a given level and type of radiation, this design is estimated to increase the rate by a factor of about 3 over that of a symmetrical design.

The rates of upsets can be estimated by a state-space-analysis technique based on the use of a mathematical model of the memory cell with drains of various sizes. The technique is illustrated in Figure 2, where the horizontal and vertical axes represent the voltages on nodes *b* and *a* of Figure 1, respectively. If the voltage on node *a* is initially made higher than the critical voltage by a pulse of ionizing radiation, the cell will change state. For example, if node *a* is initially held at a low voltage and is suddenly raised past the critical voltage by the impact of an energetic ion, then the logic state of the cell will change from "zero" to "one".

In general, the critical deposited charge that causes a given kind of upset depends on these voltage-state-space relationships and the capacitances of the nodes. The sizes and asymmetry of the drains can be chosen not only to make the cell less sensitive (higher critical charge) but also to make one-to-zero upsets more likely than zero-to-one upsets (or vice versa).

This work was done by Martin G. Buehler of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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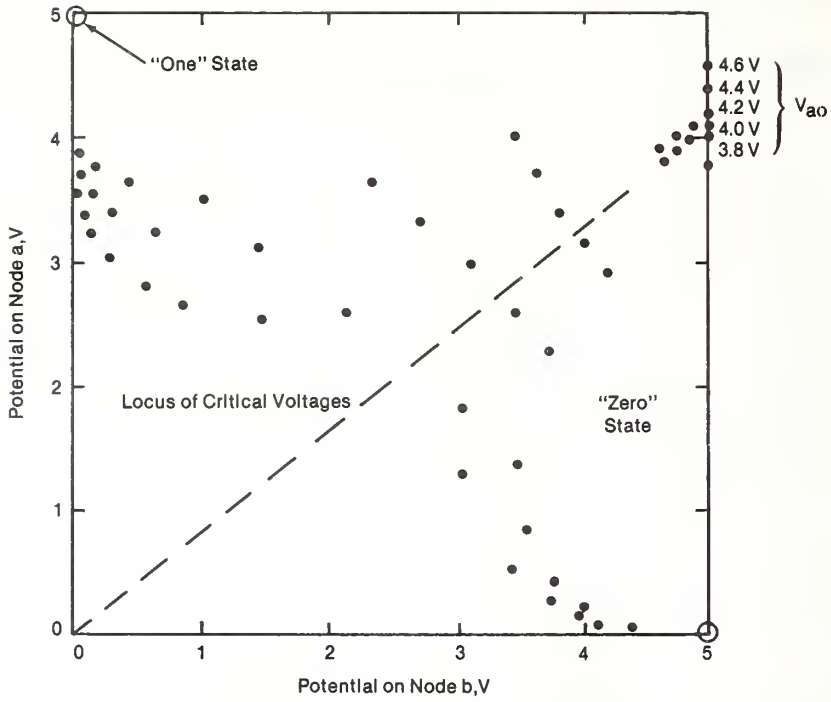

Figure 2. **State-Space Analysis** is used to analyze the single-event-upset behavior of a memory cell like that shown in Figure 1. When the voltage on node a is set at one of the indicated initial values V_{ao} and then released, the voltages on nodes a and b then follow the indicated trajectory to a final logic "one" or logic "zero" state.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Counterrotator and Correlator for GPS Receivers

All-digital design provides high accuracy and reduces cost.

An accurate, all-digital, high-speed processor comprising a correlator and downconverter has been developed for receivers in the Global Positioning System (GPS). This processor reduces roundoff and commensurability errors to extremely small values. The use of digital chip and phase advancers provides outstanding control and accuracy in phase and feedback. Great flexibility is imparted by the provision for arbitrary starting time and integration length. A minimum-bit design requires a minimum number of logical elements, thereby reducing the size, power, and cost.

The digital baseband processor in a GPS receiver (see Figure 1) consists of two major components: the tracking processor and the high-speed digital processor (see Figure 2). Control information sent by the tracking processor consists of the starting time, the sum interval length, the initial phase and phase rate, and the initial delay and delay rate. Based on this input, the high-speed digital processor accepts input data sampled at 1.5 to 2 MHz for the C/A channel and 15 to 20 MHz for the P channel and counterrotates the carrier, cross-correlates with the pseudorandom code, and accumulates the result over a nominal 20-ms interval.

All high-speed components are timed by the P or C/A sampling clock. The resulting correlation sums are collected by the tracking processor and reduced to extract measured phase, delay, and data bits. The tracking processor analyzes these phase and delay values, averages them to obtain feedback values to drive the digital equipment, and averages them over longer time intervals to reduce the output data rate.

Because all operations, including carrier downconversion, are digital, the phase and delay can be tracked and measured with extremely small errors. Great flexibility in control is provided by the fact that this design requires user-supplied values for starting time, integration length, phase, phase rate, delay, and delay rate. Another flexible feature of this design is the sampling rate. The design itself does not restrict the rate range of the sampling clock.

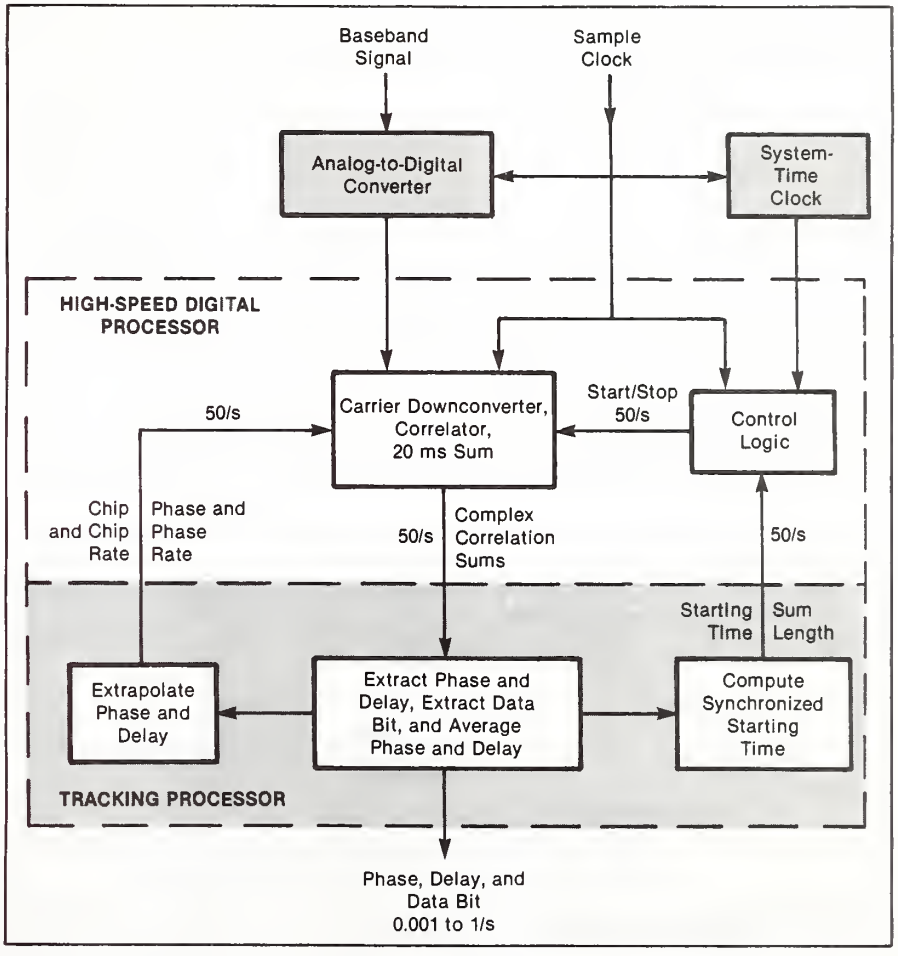
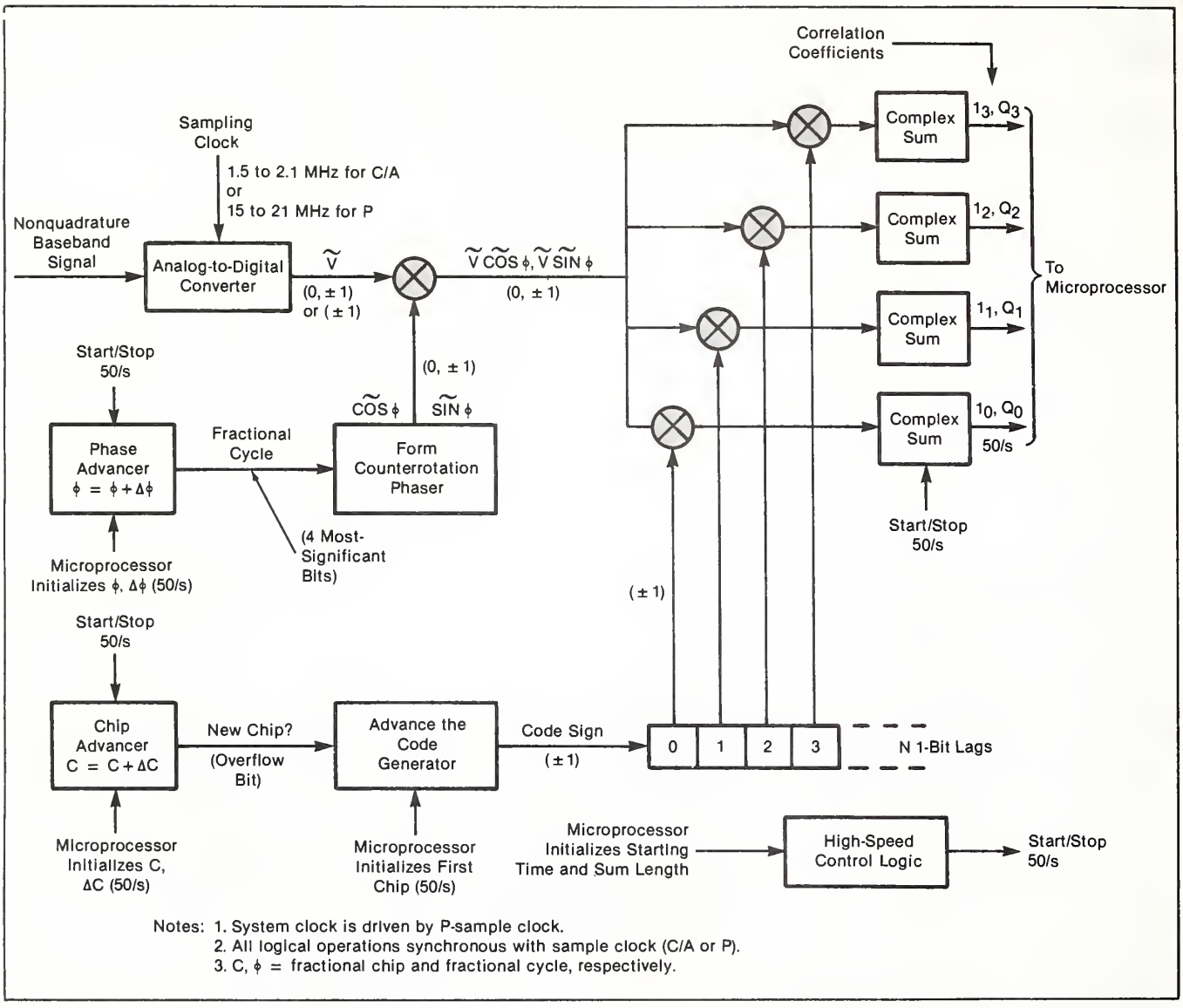


Figure 1. The **Digital Baseband Processor** in a GPS receiver recovers weak signals modulated by pseudorandom sequences.

Limits on the sampling rate will be set by the speed range of the specific equipment.

Even though the basic design would apply to any number of levels per sample, the minimum-bit design has been illustrated in Figure 2. In this design, there is a voltage loss of 4 percent in the voltage signal-to-noise ratio (SNR) due to three-level quantization of the downconversion sinusoids and a 20-percent loss if two-level sampling of the baseband signal is used. If three-level sampling is used, there is a loss of approximately 10 percent. If these small losses are acceptable in a given application, one can implement the minimum-bit design and arrive at a digital logic with a minimum number of logical elements, thereby greatly reducing the size, power consumption, and cost of the chip(s) fabricated to carry out these operations.

The design can also be used for quadrature processing, even though Figure 2 illustrates a single nonquadrature channel. To process complex signals, the operations are applied separately to each quadrature channel in parallel equipment channels. Both quadrature channels can be served by the same circuitry for generation of the delay code and counterrotation phasers. At the end of an integration inter-



Notes: 1. System clock is driven by P-sample clock.
2. All logical operations synchronous with sample clock (C/A or P).
3. C, ϕ = fractional chip and fractional cycle, respectively.

Figure 2. The **High-Speed Digital Processor** is accurate, flexible in operation, compact, conservative of energy, and relatively low in cost.

val, subsequent processing combines the complex sums with appropriate signs for the real and imaginary parts.

This work was done by J. Brooks Thomas, Jeffrey M. Srinivasan, and Thomas K. Meehan of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

High-Performance Power-Semiconductor Packages

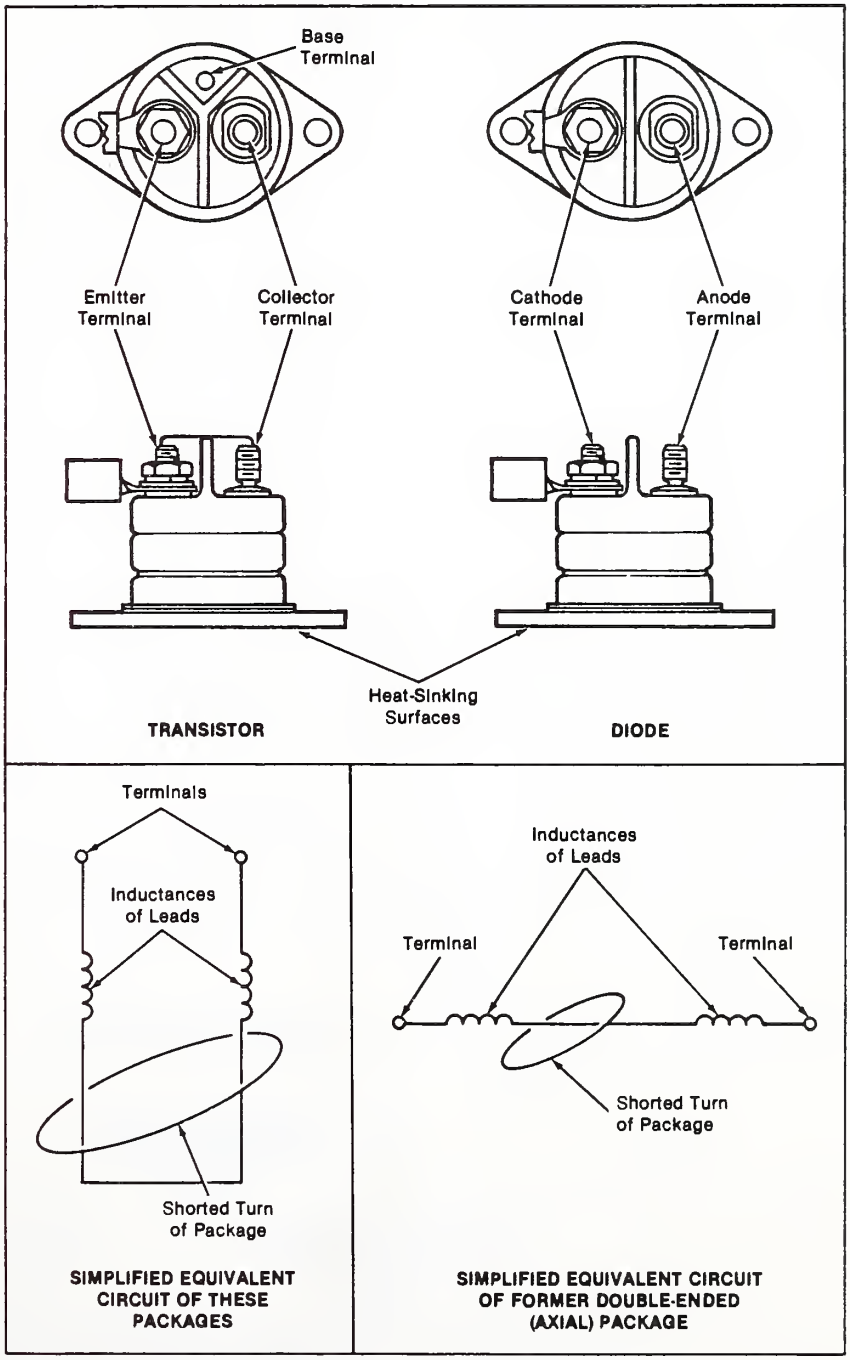
A diode and a transistor satisfy stringent design criteria.

A 600-V, 50-A transistor and a 1,200-V, 50-A diode in rugged, compact, lightweight packages are intended for use in inverter-type power supplies that have switching frequencies up to 20 kHz. The packages provide low-inductance connections, low loss, electrical isolation, and a long-life hermetic seal. The design of the packages solves the historical problem of separation of the electrical interface from the thermal interface of a high-power semiconductor device.

The low inductance is achieved by making all electrical connections to each package on the same plane (see figure). This also reduces high-frequency losses by reducing coupling into the inherent shorted turns in the packaging material around the conductor axes. Stranded internal power conductors aid conduction at high frequencies, where the skin effect predominates. Other conductors are large and made of oxygen-free, high-conductivity copper for low electrical resistance. All conductors are made as short and thick as possible to minimize inductance. The insulators have high dielectric strength and a low dissipation factor.

The semiconductor device is electrically isolated from the package by a beryllia pad. The prime consideration in the design is the transfer of heat generated by the device to the heat sink, and beryllia was chosen because it provides the requisite electrical insulation yet is sufficiently thermally conductive. This feature also reduces the capacitance between the device and the heat sink, thereby reducing both the radiation of electromagnetic interference and common-mode currents in the heat sink.

Both semiconductor devices have glass-passivated junctions. All electrically active components are isolated from the main body of each package by insulation designed to withstand a potential of 2,500 V between the bottom plate of the package and the collector of the transistor or the anode of the diode. The hermetic seal of the package retains an atmosphere of nitrogen. All of the interior surfaces are coat-



All Electrical Connections are made on a plane at the upper end of the package. This reduces inductance and the losses due to the shorted-turn effect of the package materials.

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ed with an extra insulating layer of parylene. If the hermetic seal is broken, this coat enables the device to passthrough the Paschen minimum-breakdown voltage without failure and protects the electrical parts from the environment.

Each package fits within a rectangular parallelepiped of 1.445 by 2.250 by 1.640 in. (36.7 by 57.2 by 41.7 mm). The complete diode and transistor packages weigh 84.5 and 86.0 g, respectively.

This work was done by David Renz and Irving Hansen of **Lewis Research Center** *and Albert Berman of Microsemi Corp. Further information may be found in NASA CR-180829 [N87-28825], Price Code: A06 "Space Station Power Semiconductor Package Development."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14818/TN

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Chip Advancer for GPS Receiver

Instrumental errors can be made negligible.

In a Global Positioning System (GPS) receiver, a pseudorandom code sequence can be generated by simple digital logic that incorporates the effects of time, the delay, and the rate of change of the delay. For each integration interval, both the delay and the rate of change of the delay can be initialized to a small fraction of a chip — for example, to the order of 10^{-7} — thereby making feedback control and the extraction of delay highly accurate and flexible. With appropriate selection of the sampling rate relative to the chip rate, commensurability errors can be reduced to extremely small levels.

By supplying the proper initial integer chip value to initialize the code generator and the proper fractional chip and chip rate for the chip advancer, external hardware or software can control a code sequence that starts at a fraction of a given chip and advances at the selected chip rate. In a GPS receiver, the initial chip value (integer plus fractional parts) would be based on the starting time and the feedback delay, while the chip rate would be equal to the sum of the rate of change of the delay and the fundamental chip rate divided by the sample rate. The chip advancer is activated and deactivated by a "start" line. Over a correlation interval, the model delay consists of a linear time function.

As illustrated in the figure, the chip advancer is initialized by external hardware or software that supplies an initial fractional-chip value in the form of an integer equal to the fractional chip times 2^N and a chip rate in the form of an integer equal to the chip rate (in chips per sample point) times 2^N, where N is the number of bits in the fractional-chip register. Simultaneously, the external device also initializes the registers of the code generator so that the code generator will produce the correct code sign for the first sample point.

When processing is started, the chip advancer is clocked by the sampling clock. For each new sample point, the chip advancer adds the number in the rate register to the number in the fractional-chip register. When the fractional-chip register overflows, indicating a transition to a new chip, a pulse is generated. That pulse triggers enabling logic circuitry that lets the concurrent sampling clock advance the code generator to the next chip. If the code generator does not receive a new-chip-advance signal for a given sample point, the previous code sign persists for that sample.

If selected sampling rate is effectively incommensurate with the fundamental chip rate, the integrated error due to discrete sampling of the model code sequence can be reduced to negligible levels after integration over a fairly short time. In selecting a sampling rate, it is advisable to choose a value that is sufficiently removed from highly commensurate ratios (e.g., 2/1, 3/2, etc.) so that the Doppler shift cannot change the chip rate to a value highly commensurate with the sampling rate.

An important option in using the chip advancer is that the starting chip value, including the fractional chip, can be set exactly every sum interval. Thus, the measured delay will be corrupted by roundoff errors at the level of 2^{-N} or less, which is less than 100 nanochips for a 24-bit chip advancer. The buildup of the roundoff error due to roundoff in the rate register can be eliminated by computing the roundoff accumulation and offsetting the initial delay to compensate. Further, the flexibility of accurately resetting the chip and the chip rate for each correlation interval is very useful in many applications; for example, those involving multiplexing schemes. The flexibility in the starting time and the sum interval is very useful in aligning the correlation interval with the beginnings and endings of data bits.

This work was done by Thomas K. Meehan, Jeffrey M. Srinivasan, and J. Brooks Thomas of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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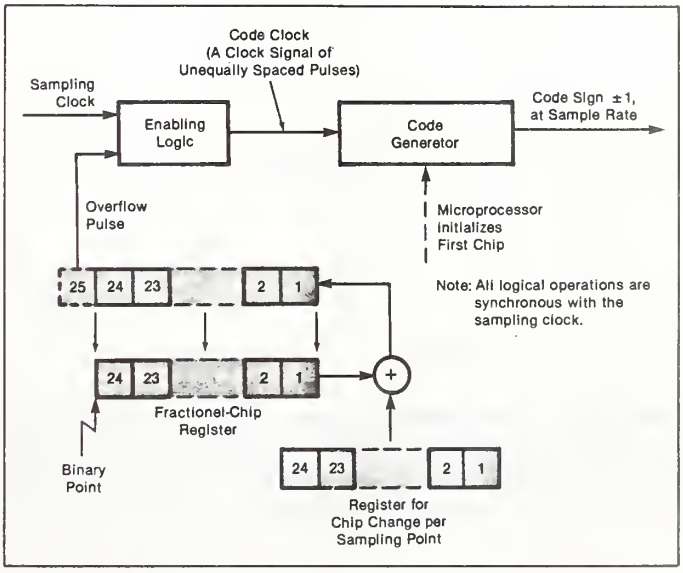

The **Chip Advancer**, part of a correlating receiver, advances a pseudorandom sequence of data in small increments.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Monolithic III–V/Silicon Spatial Light Modulator

A silicon-based version provides for a choice of auxiliary on-chip circuitry.

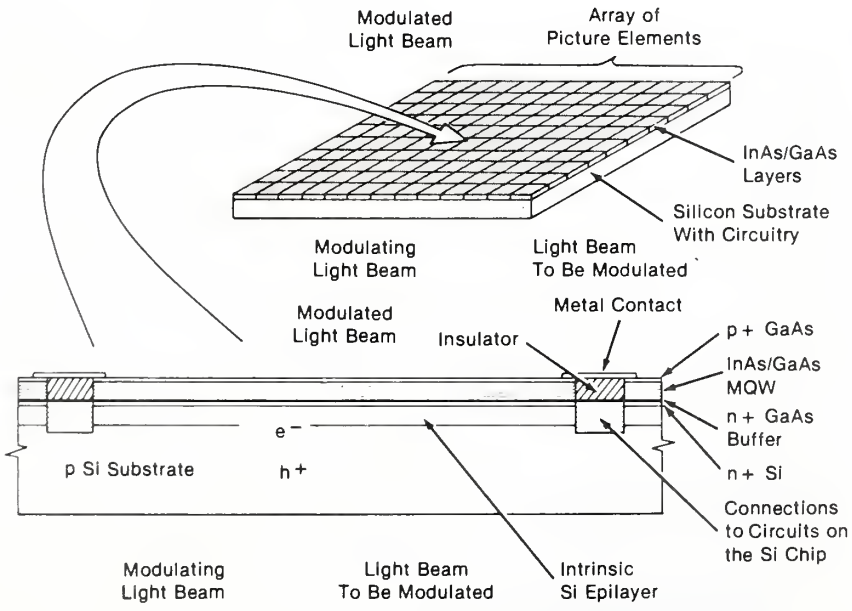
Current techniques for the growth of device-quality GaAs on silicon substrates should enable the fabrication of a proposed silicon-based version of a photodiode-coupled spatial light modulator. High-density, two-dimensional arrays of picture-element modulators (e.g., a 1,000- by 1,000-element array on a 2-cm-square chip) could be used for real-time processing of images or parallel processing of arrays of data at very high throughput rates. The use of silicon would make available a wider range of auxiliary on-chip signal-processing circuitry for the coding and decoding of data, the addition or subtraction of brightness levels, spatial reformatting, and rescaling.

The proposed modulator would be a layered structure grown on a silicon substrate (see figure). First, a p-doped/intrinsic/n-doped (PIN) photodiode would be formed on the silicon substrate. Then a GaAs buffer layer would be grown over the silicon to form a suitable base for the growth of the InAs/GaAs multiple-quantum-well (MQW) PIN diode structure.

The relative positions of the two diodes would be reversed from those in the original version of the GaAs-based modulator (NPO-16298). The principle of operation is the same, however. The photo-carriers produced by the absorption of the modulating signal (photons of energy greater than the 1.1-eV band gap of Si) in the PIN diode would change the voltage on the MQW diode, and thus the field acting on the MQW's, controlling its transmission of the signal to be modulated (photons of energy near the MQW exciton level and less than the Si band gap). As in the original modulator, the use of InAs/GaAs allows the modulated light signal to pass freely through the substrate and offers the flexibility of tailoring the quantum level of the MQW structure to adjust the wavelength of the modulated beam to values often used with fiber optics; e.g., 1.3 or 1.5 μm.

The confinement of misfit dislocations generated by the 4-percent mismatch between the GaAs and Si lattices and the critical problem of control of the initial nucleation of GaAs on Si is being solved in several laboratories world-wide by using modulated-beam epitaxy and related vapor-phase deposition techniques.

This work was done by Joseph Maserjian and Sverre T. Eng of Caltech for **NASA's Jet Propulsion Laboratory**.



A **Monolithic Photodiode-Coupled Light-Modulator Array** could be constructed on a silicon substrate by growing InAs/GaAs multiple-quantum-wells over a silicon PIN diode layer. An intermediate GaAs buffer layer would confine lattice-misfit dislocations to the vicinity of the silicon.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Process for Patterning Dispenser-Cathode Surfaces

Microfabrication techniques increase uniformity.

Several microfabrication techniques have been combined into a process that cuts slots 100 μm long and 1 to 5 μm wide into tungsten dispenser cathodes for traveling-wave tubes. The slots enable a more-uniform low-work function coating to be dispensed to the electron-emitting surface. The emission of electrons therefore becomes more uniform over the cathode surface.

A molybdenum mandrel is coated by chemical-vapor deposition with a layer of tungsten 25 μm thick, followed by a layer of aluminum 5 μm thick. A layer of photoresist 1 μm thick is applied over the aluminum. Slots are cut in the photoresist by writing with a laser beam, electron beam, or ion beam, exposing parts of the underlying aluminum film (see Figure 1). The aluminum under the slots is etched away by chemically-assisted ion-beam etching, a process in which chlorine gas and a beam of xenon ions are directed into the slots in the photoresist (see Figure 2). The beam of ions enhances the chemical reactivity of the aluminum with the chlorine, forming a volatile product that is pumped away. The resulting pattern of slots in the aluminum, which is identical to the pattern in the photoresist, exposes the underlying tungsten.

Another chemically-assisted ion-beam etching step follows. Fluorine or chlorine trifluoride gas and a beam of xenon ions are directed at the exposed tungsten, etching slots into it. The aluminum acts as a mask because it reacts only slightly with either gas. If slots narrower than 1 μm are needed, the patterned cathode can be coated with more tungsten by chemical-vapor deposition to close partially the gaps between the walls of the slots.

This work was done by Charles E. Garner and William D. Deininger of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17183/TN*

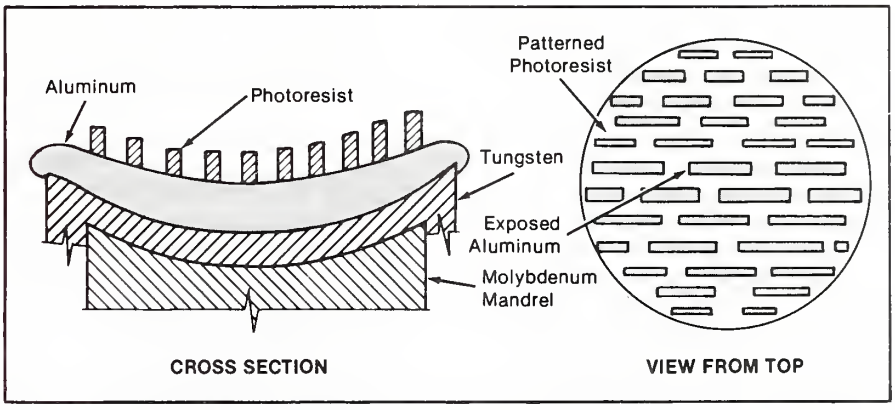

Figure 1. The **Patterned Photoresist** serves as a mask for etching the underlying aluminum.

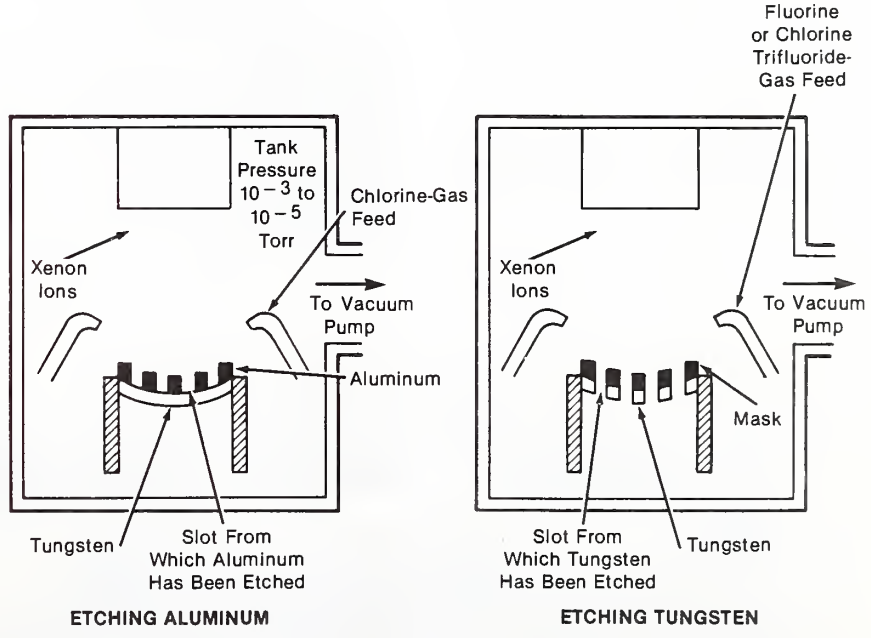

Figure 2. **Chemically-Assisted Ion-Beam Etching** with chlorine removes exposed parts of the aluminum layer (left). Chemically-assisted ion-beam etching with fluorine or chlorine trifluoride removes the tungsten not masked by the aluminum layer (right).

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Stabilizing Semiconductor Devices With Hydrogen

Damage by radiation would be healed rapidly.

Palladium would be incorporated into semiconductor devices to store hydrogen near the active regions, according to a proposal. This feature would provide the continuous, rapid recovery of the devices from degradation caused by hot electrons, photons, and ionizing radiation.

In a metal-oxide/semiconductor device, ionizing radiation degrades performance by causing charges to be trapped in the oxide and by generating undesired interface states at the Si/SiO_2 interface. In a very-large-scale integrated circuit with channel lengths of about 1 μm or less, the injection of hot carriers from the channels into the oxide also generates interface states, which can degrade the characteristics of transistors to the point of failure. In amorphous-silicon solar cells, ionizing radiation gives rise to electronic traps and recombination centers in the active region, which decrease the energy-conversion efficiency.

In these devices, the damage involves the breaking of existing bonds between hydrogen and silicon atoms or the creation of new unsaturated bonds between silicon atoms. The deleterious effects can be reversed quickly by providing atomic hydrogen to passivate the unsaturated silicon bonds. The hydrogen can be stored in palladium, which also catalyzes the dissociation of hydrogen from the diatomic molecular to the monatomic form.

The figure shows several candidate sites for palladium film catalysts, which would be inserted during manufacture as integral parts of the devices. The palladium films could be made by evaporation, sputtering, or chemical-vapor deposition. If additional storage were required, a thick layer of palladium could be plated on the inside of the package that surrounds the device. The hydrogen would be stored by exposing the palladium to hydrogen gas just before the package is sealed hermetically.

This work was done by Albert W. Overhauser and Joseph Maserjian of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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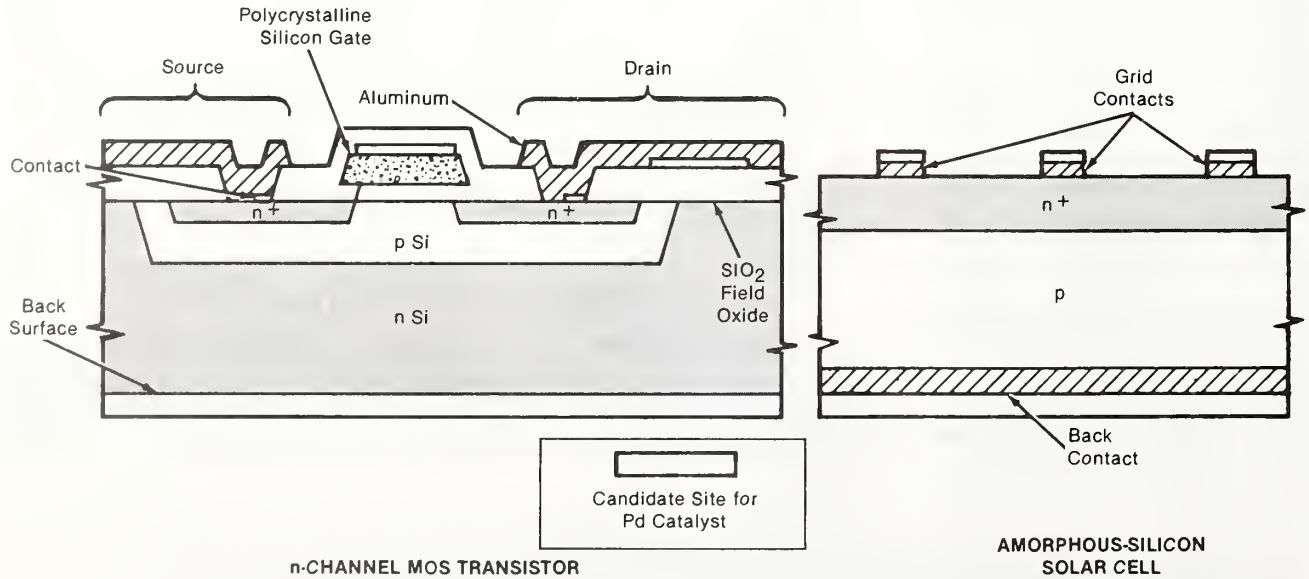

Hydrogen Could Be Stored in palladium catalysts at one of the candidate sites shown in heavy colored lines.

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National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Ultra-Stable Superconducting-Maser Oscillator

Frequency fluctuations would be reduced to as little as 2×10^{-19}.

Unprecedented stability of frequency in a superconducting, triple-cavity ruby maser oscillator would be achieved by the incorporation of a proposed amplitude-control subsystem. At present, fluctuations in frequency of 10^{-16} represent the state of the art. The new design should enhance ultra-stable measurements of time by reducing the fluctuations to 2×10^{-19} routinely, and to as little as 10^{-20} in exceptional cases.

Fluctuations in the amplitude of the oscillator signal cause fluctuations in the polarization magnetic field in the ruby, which is the active element of the oscillator. Because the magnetic field affects the frequency of oscillation, the amplitude fluctuations result in frequency fluctuations; in fact, the change in frequency is a known function of the change in amplitude. Heretofore, amplitude (and, therefore, frequency) fluctuations have been controlled by placing a power detector and an electronically variable attenuator at room temperature in the pump-signal transmission line. However, this configuration is insensitive to changes in amplitude that occur in the transmission line beyond the power detector or in the ruby itself.

In the new system (see figure) currents are induced in a superconducting pickup coil by changes in the magnetic field in the ruby. The currents from the coil are fed to a superconducting quantum-interference device (SQUID) magnetometer, the output of which is used to generate the control signal for the electronically variable attenuator. Thus, the attenuator varies the pump-signal amplitude in response to the magnetic-field fluctuations in the ruby. A very high feedback-loop gain is used for sensitivity of control and adequate compensation of fluctuations.

This work was done by Donald M. Strayer and G. John Dick of Caltech for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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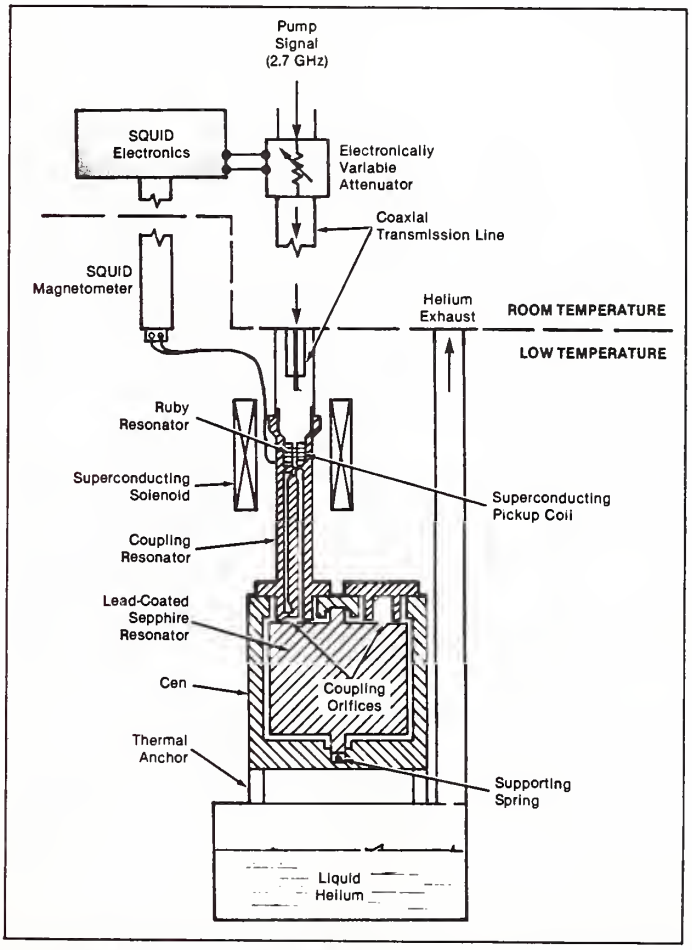

In the **Ultra-Stable Superconducting-Maser Oscillator**, the amplitude (and, therefore, the frequency) of oscillations is controlled in response to the condition of the active ruby element at low temperature. In the previous design, the amplitude was stabilized at a point in the transmission line, at room temperature.

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NASA Tech Brief
National Aeronautics and
Space Administration

Computer-Aided Engineering of Cabling

This program generates data sheets, drawings, and other information on electrical connections.

DFACS is an interactive multiuser computer-aided-engineering tool for system-level electrical integration and cabling engineering. The purpose of the program is to provide the engineering community with a centralized data base for putting in, and gaining access to, the functional definition of a system as specified in terms of details of the pin connections of the end circuits of subsystems and instruments and data on harnessing. The primary objective is to provide an instantaneous single point of interchange of information, thus avoiding error-prone, time-consuming, and costly shuttling of data along multiple paths.

The DFACS program, which is centered around a single data base, has built-in menus that provide easy input of, and access to, data for all personnel involved in the system, subsystem, and cabling. The DFACS program enables the parallel design of circuit-data sheets and drawings of harnesses. It also recombines raw information to generate automatically various project documents and drawings, including the index of circuit-data sheets, the list of electrical-interface circuits, lists of assemblies and equipment, cabling trees, and drawings of cabling electrical interfaces and harnesses.

Real-time automatic production of harness drawings and circuit-data sheets from the same reservoir of data ensures instant harmony in the engineering design of the system and cabling. DFACS also contains automatic wire-routing procedures and extensive error-checking routines designed to minimize the possibility of engineering error.

The DFACS program was developed in 1987. It is designed to operate on a DEC VAX minicomputer or microcomputer using INGRES Version 5.0/03 and VAX.VMS/04. INGRES is available through Relational Technology, Inc.

This program was written by Joseph W. Billitti of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17391/TN*

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NASA Tech Brief
National Aeronautics and Space Administration

Designing Corrector Optics

Image-spot radii can be reduced by factors ranging from 5 to 25.

Corrector Surface Design Software (CORFIG) calculates the optimum figure of a corrector surface for an optical system based on real ray traces. CORFIG generates the corrector figure in the form of a spline data-point table and/or a list of polynomial coefficients. The number of spline data points as well as the number of coefficients are specified by the user.

First, the parameters of the optical system (thicknesses, radii of curvature, and the like) are entered. CORFIG traces the outermost axial real ray through the uncorrected system to determine approximate radial limits for all rays. Then several real rays are traced backward through the system from the image to the surface that originally followed the object, within these radial limits. At this first surface, the local curvature is adjusted on a small scale to direct the rays toward the object, thus removing any accumulated aberrations.

For each ray traced, this adjustment is different, so that at the end of this process the resultant surface is made up of many local curvatures. The equations that describe these local surfaces, expressed as high-order polynomials, are then solved simultaneously to yield the final surface figure, from which data points are extracted. Finally, a spline table or list of polynomial coefficients is extracted from these data points.

CORFIG is intended to be used in the late stages of optical design. The design of the system must have at least a good paraxial foundation. Preferably, the design should be at a stage at which traditional methods of correction of Seidel aberrations do not bring the size of an image spot within specification.

CORFIG reads the system parameters of such a design and calculates the optimum figure for the first surface such that all of the original parameters remain unchanged. Depending upon the system, CORFIG can reduce the root-mean-square image-spot radius by a factor of 5 to 25. The original parameters (magnification, back focal length, and the like) are maintained because all rays upon which the corrector figure is based are traced within the bounds of the outermost ray of the original system. For this reason, the original system must have a certain degree of integrity.

CORFIG optimizes the figure of the corrector surface for on-axis images at a single wavelength only. However, it has been demonstrated many times that the method of CORFIG also significantly improves the quality of field images and images formed at wavelengths other than the design wavelength.

CORFIG is written completely in VAX FORTRAN. It has been implemented on a DEC VAX-series computer under VMS with a central-memory requirement of 55K bytes. The program was developed in 1986.

This program was written by A. Dantzler of **Goddard Space Flight Center.**
GSC-13120/TN

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NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Evaluation of High-Frequency Power Meters

Accurate power measurements are fundamental to assessing the performance of almost all radiofrequency, microwave, and millimeter wave equipment. Power considerations are also crucial for the design of efficient, cost-effective, and safe systems. Measurements at these higher frequencies are affected by many factors. Impedance mismatch, interference, leakage, nonlinear effects, and other sources of error must be assessed and minimized. A NIST publication, Performance Evaluation of Radiofrequency, Microwave, and Millimeter Wave Power Meters (NIST TN 1310), describes measurement techniques for evaluating the electrical performance of certain commercially available power meters that use bolometric sensors and operate typically from 10 MHz to 26.5 GHz.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PB 89-193916NAC
Price code: A07

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Automatic Parametric Testing of Integrated Circuits

A software system generates its own test instructions and teaches itself new tests.

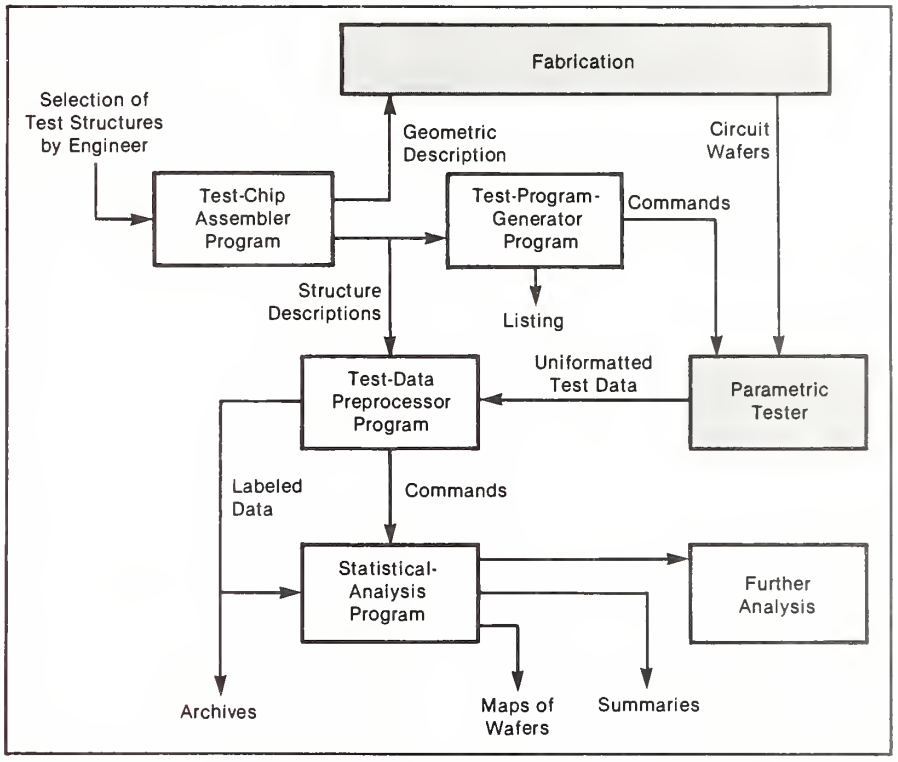
A computer program for parametric testing saves time and effort in research and development of integrated circuits. The software system automatically assembles various types of test structures and lays them out on a silicon chip, generates a sequence of test instructions, and interprets the test data. The system employs self-programming software; it needs a minimum of human intervention. It can be adapted to the needs of different laboratories and can readily accommodate new test structures.

The designer of an integrated circuit decides on the type and number of test structures — transistors of various polarities and sizes, split-bridge resistors, van der Pauw crosses, and the like. With this information, the system automatically generates the geometrical specifications for the test structures that are to be built into the integrated circuit. The specifications are used to fabricate silicon wafers containing the circuit (see figure). Meanwhile, the system produces instructions for testing the chip.

If the engineer devises a new test structure, the system teaches itself how to specify and lay out the new structure and determines how it should be tested. The engineer merely adds a few lines about the new structure in a declaration file; the engineer does not have to make any changes in the test-program-generator portion of the software.

The program reduces the large amount of data on the structures to statistical summaries for individual wafers and for entire lots of wafers. Additional programs use the statistical summaries to perform such tasks as high-level analysis, extraction of parameters, and mapping of wafers.

The program codes are designed to be adaptable to most computers and test equipment now in use. They are written in high-level languages to enhance transportability.



The **Parametric-Testing Software System** proceeds from the engineer's selection to control automatically the fabrication of test structures in integrated circuits, the operation of the testing equipment, and the analysis of the test data. The system also produces program listings in easily read form.

This work was done by Glenn A. Jennings and Cesar A. Piña of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-16783/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Achromatical Optical Correlator

The signal-to-noise ratio should exceed that of a monochromatic correlator.

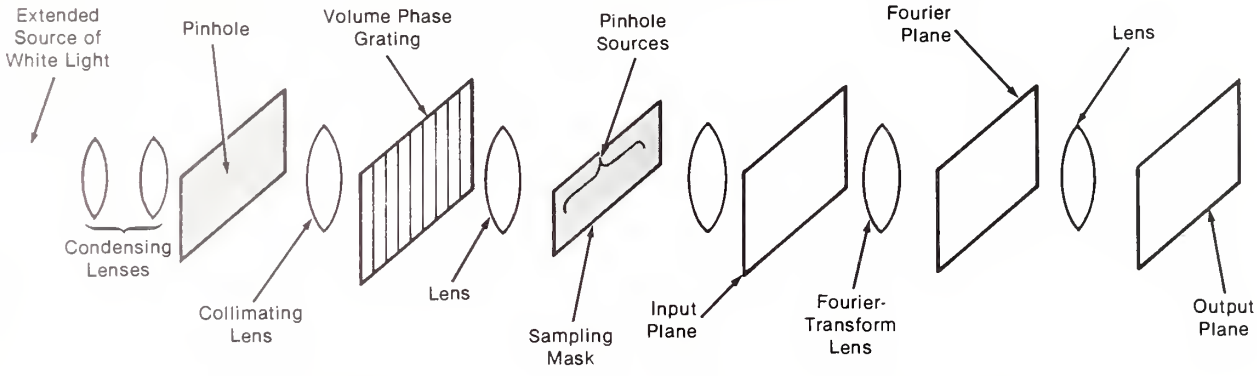
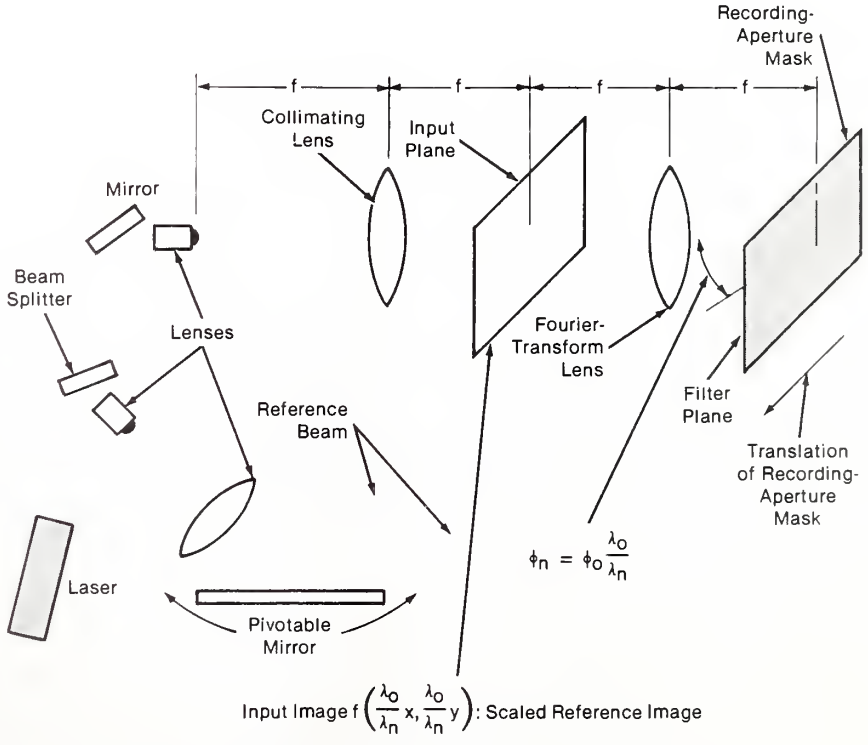


Figure 1. The **Achromatical Optical Correlator** uses multiple-pinhole diffraction of dispersed white light to form superposed multiple correlations of the input and reference images in the output plane.

An experimental optical image-correlating device is illuminated by multiple-pinhole diffraction of dispersed white light instead of the monochromatic, coherent light usually employed in holographic systems. The use of noncoherent light is expected to increase the signal-to-noise ratio by reducing the component of noise attributable to the unwanted component of interference in coherent light. Furthermore, noncoherent illumination is suitable for applications involving the recognition of color and the determination of scale. When fully developed, achromatical correlators are likely to be useful for the recognition of patterns; for example, in industrial inspection and the search for selected features in aerial photographs.

The achromatical correlator is illustrated schematically in Figure 1. White light is condensed onto a pinhole, then converted by two lenses and a grating into a horizontal-line spectrum. A sampling mask is placed so that a horizontal linear array of pinholes lies in the line spectrum. Thus, each pinhole acts as a point source of light over the narrow range of wavelengths that illuminates it.

The light from the pinholes is recollimated into multiple plane waves of different tilts and passed through the input plane, which contains a transparency of the image to be tested. A lens then focuses the light into multiple discrete Fourier spectra of this input image, each such spectrum being the Fourier transform of the in-



Notes: 1. f = focal length.
2. λ_o = laser wavelength.
3. λ_n = wavelength at nth pinhole source.
4. ϕ_n = angle of reference beam for λ_n.

Figure 2. The **Set of Matched Spatial Filters** is made by a multiple-exposure holographic process, each exposure using a suitably-scaled input image and a suitable angle of the reference beam. The recording-aperture mask is translated to the appropriate horizontal position for each exposure.

put object at the wavelength of one of the pinhole sources.

Essential to the achromatical correlator is a set of matched spatial filters. Each such filter contains the Fourier transform, at the wavelength of one of the pinhole sources, of a scaled version of the reference image with which the input image is to be compared. Provided that the set of matched spatial filters is aligned correctly in the Fourier-transform plane, the image formed in the output plane is a superposition of the correlations between the input and reference images at the wavelengths of the pinholes.

The matched spatial filters are made by using a laser to make a Fourier hologram at the Fourier-transform plane as shown in Figure 2. For this process, the input image to produce the filter for each pinhole wavelength is the reference image scaled by the ratio of the laser wavelength to the wavelength at the pinhole. A pivotable mirror is used to tilt the reference beam to the angle appropriate to this wavelength.

This work was done by Tien-Hsin Chao and Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17206/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Energy

1026 Cascade Cell Sets Record Efficiency (Licensing Opportunity)

1027 Gravimetric Separation Technique

1028 Infiltration Reduction for Single-Family Houses

1029 Advanced Fuel-Cell Modules—Modules are designed for long life, light weight, reliability, and low cost.

1030 Choosing Compositions of Electrocatalysts—The best alloys for fuel cells and batteries can be determined from thermodynamical considerations. (Licensing Opportunity)

Testing & Instrumentation

1031 New Device Saves Electronic Components

Other Items of Interest

1001 Enhanced Process Increases Ethanol Yield

1007 Single-Board Microcontroller Suitable for Rapid Prototyping

1043 Energy-Efficient, Continuous-Flow Ash Lockhopper—Pressure balance in the control gas prevents the loss of reactor gas. (Licensing Opportunity)

1047 New Acoustic Detection System Developed (Licensing Opportunity)

1062 Electrophoretic Coating Process Finding New Applications

1065 High-Quality Amorphous Silicon Films Produced

1073 Microencapsulated Phase-Change Materials for Storage of Heat—Investigations concentrate on the feasibility of practical, safe, lightweight systems.

Department of Energy

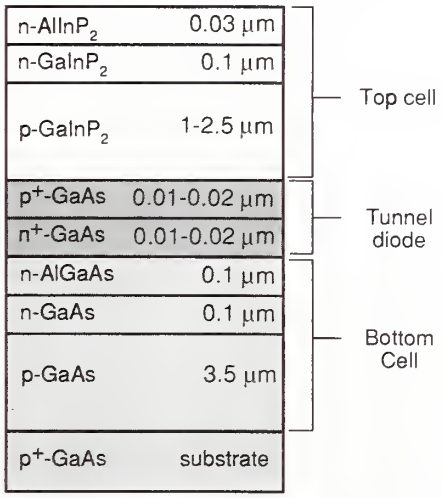
Technology Application

Solar Energy Research Institute

Cascade Cell Sets Record Efficiency

SERI's patented cascade cell has achieved 25% efficiency, the highest ever recorded for a photovoltaic device of this type. The recent 15% gain is a major step in the development of economically feasibile photovoltaic systems.

Cascade cells use layered materials to convert more of the solar spectrum to electricity. SERI's two-terminal, tunnel-junction-connected cell employs a special combination of gallium indium phosphide ($GaInP_2$) and gallium arsenide (GaAs), which have similar atomic spacing and complementary optical properties. Mismatched atomic spacing has been a key problem in cascade cell technology.



Structure of SERI's patented cascade cell.

Recent research improved the efficiency of SERI's cell from 21.8% to 25%. Progress is attributed to an improved aluminum indium phosphide window as well as a more detailed understanding of $GaInP_2$ properties and the development of a computer code for modeling the photocurrent response of this type of cell.

Further research using alloys such as aluminum gallium arsenide and gallium indium arsenide is expected to push cell efficiency as high as 30%.

For Additional Information:

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Refer to Volume XI, Number 2/TN

Department of Energy

Technology Application

Pittsburgh Energy Technology Center

Gravimetric Separation Technique

Pittsburgh Energy Technology Center (PETC) has developed a centrifugal gravimetric technique to evaluate the clean-ability of coals crushed to ultra-fine sizes. This technique incorporates a dispersing agent, ultrasonic treatment (both are used to keep the coal from agglomerating or lumping), and a drying procedure - all refinements not used in older techniques.

The advantages show up in a statistical evaluation. Eight different variables were tested, and the results were superior to those of the old process. Industry and academia currently use the technique to predict the cleaning potential of fine and ultra-fine coal. Study in the fields of fundamental research and surface chemistry may also benefit from its use.

For more information contact Kay Downey (412) 892-6029.

Department of Energy

Technology Application

Oak Ridge National Laboratories

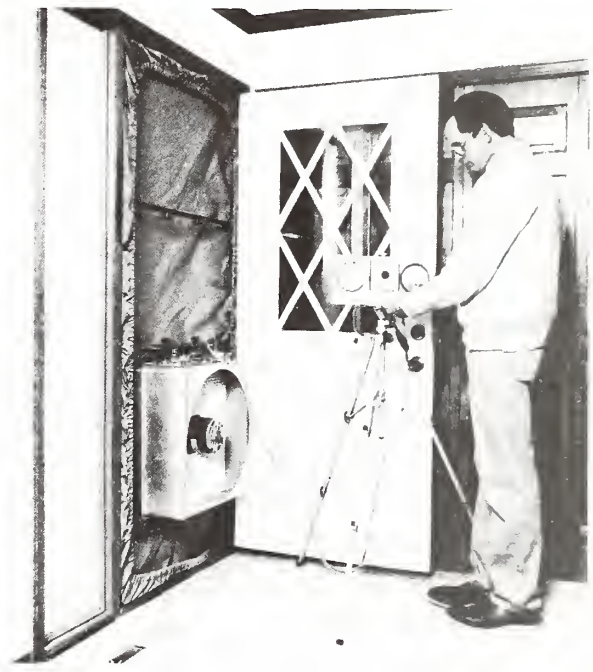
Infiltration Reduction for Single-Family Houses

Standard infiltration retrofit procedures to improve a house's thermal efficiency often include routine caulking or weather-stripping of doors and windows. However, these areas may not be the major contributors to a home's infiltration problems; walls, ceilings, attic accesses, fireplaces, electrical outlets, or other areas may also need attention. A house having too little infiltration or ventilation can also have problems. Standards must be met to protect the integrity of the structure and the health and comfort of its occupants.

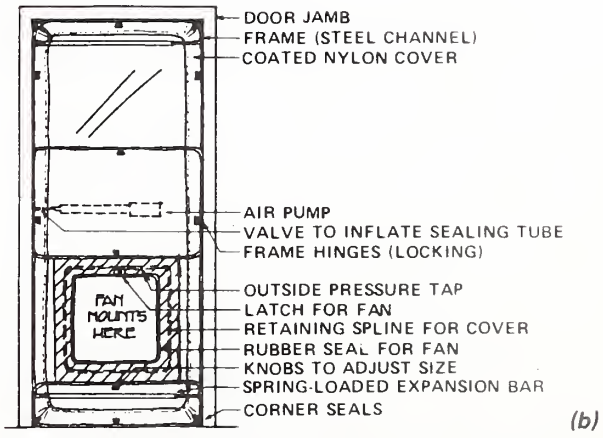
The DOE Office of Buildings and Community Systems' Building Energy Retrofit Research Program commissioned ORNL to develop a procedure by which retrofits could be made more efficiently. A joint project was carried out, during which ORNL's retrofit audit program was field-tested and an infiltration retrofit procedure developed by the Wisconsin Energy Conservation Corporation was evaluated.

The Wisconsin retrofit procedure employs a blower door, which is a device that either pressurizes or depressurizes a house to aid in locating leaks and to allow a measure of a house's leakiness. Proper use of the blower door can be a great help in identifying and repairing significant infiltration leaks within a house. A fan is mounted into the envelope of a structure, normally a door (Fig. 1). Varying the speed of the fan varies the indoor-outdoor pressure differential. Once this system is operating, leaks can be pinpointed by feeling for drafts or by observing the movement of smoke produced by smoke sticks.

To measure the effects of infiltration retrofits, both the pressure differential and the rate of air flow through the fan are measured. The flow rate through the fan must equal the air-leakage rate from the house at the measured pressure differential. Division of this volumetric flow rate



(a)



(b)

Fig. 1. *(a)* Blower door installed. *(b)* Diagram showing the components of the blower door assembly.

by the house volume gives the number of air changes per unit of time at the pressure differential. For example, the number of air changes per hour at 50-Pa (*n*-ACH50) depressurization were used in the ORNL study to compare leakage rates before and after retrofits.

The retrofits in this study produced an average 16% reduction in air-leakage rate. For the seven houses recommended for retrofit, 89% of the targeted reductions were accomplished with 76% of the recommended expenditures. The average cost of retrofits per house was reduced by a factor of four compared with previous programs. The average payback period for recommended retrofits was 4.4 years (based on predicted energy savings computed from achieved air-leakage reductions). Although exceptions occurred, the procedure's 8-ACH50 minimum initial leakage rate for advising retrofits to be performed appeared a good choice, based on cost-effective air-leakage reduction. Houses with initial 7-ACH50 leakage rates or below consistently required substantially higher costs to achieve significant air-leakage reductions.

No statistically significant average annual energy savings were detected as a result of the study's retrofits. Measured savings for individual houses varied widely in both positive and negative directions, indicating that the results were affected by factors not considered in the study. Recommendations to improve the retrofit procedure include more extensive training of retrofit crews, checks for minimum air-exchange rates to ensure air quality, and addition of the basic cost of determining the initial leakage rate to the recommended expenditure level. Recommendations for the field test of the procedure include increasing the number of houses in the sample, timely examination of metered data to detect anomalies, and monitoring indoor temperatures. Although inappropriate in a field-test procedure, an investigation into the effects of air-leakage rate reductions on heating loads needs to be performed.

M. B. Gettings, L. N. McCold, and J. A. Schlegal, *Field Test Evaluation of Conservation Retrofits of Low-Income, Single-Family Buildings in Wisconsin: Blower-Door-Directed Infiltration Procedure, Field Test Implementation and Results*, ORNL/CON-228/P5, Oak Ridge National Laboratory (June 1988).

"Energy-Conserving Retrofit Audit for Single-Family Buildings," Bulletin No. 665, *Technology Applications Bulletins*, Oak Ridge National Laboratory.

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(815) 574-4192

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Advanced Fuel-Cell Modules

Modules are designed for long life, light weight, reliability, and low cost.

A stack of alkaline fuel cells is based on modules, each of which consists of three fuel cells and a cooler (see figure). Each cell has an active area of 1 ft^2 (0.09 m^2). The materials and configurations of the parts were chosen to extend life expectancy, reduce weight and manufacturing cost, and increase reliability.

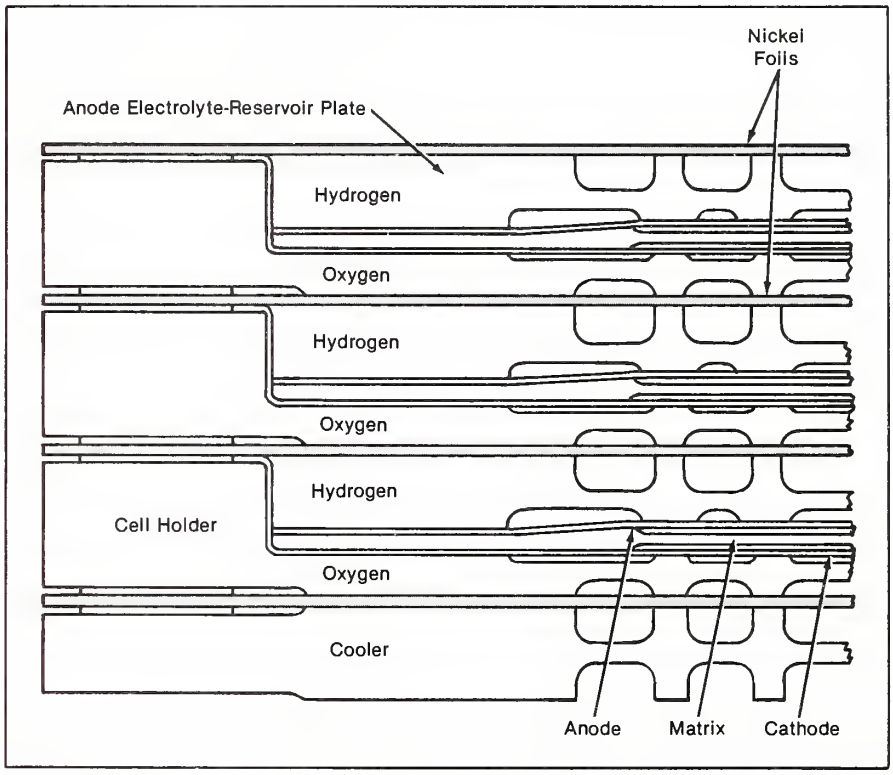
Each cell includes the following components:

- a ribbed carbon fine-pore anode electrolyte-reservoir plate,
- a platinum-on-carbon catalyst anode,
- a potassium titanate matrix bonded with butyl rubber,
- gold-plated nickel-foil electrode substrates, and
- a silver-plated, gold-flashed molded polyphenylene sulfide cell holder.

The materials were chosen for resistance to corrosion. Structural components are generally molded to reduce costs. A simple cell-edge seal further reduces costs. The use of carbon for the electrolyte-reservoir plate and a thin nickel-foil electrode substrate help to keep weight low.

Electrical current passes through the silver plating of the molded cell holder to the adjacent cell. With a current of 140 A, the voltage across the internal cell resistance is only 1.5 mV.

Manifolds in the molded cell plate and the ribbed carbon electrolyte-reservoir plate allow the circulation of oxygen and hydrogen. Manifolds in the cooler plate provide for the circulaton of coolant.



A **Stack of Cells on a Cooler** constitutes a fuel-cell module. Oxygen flows through the upper part of a cell, and hydrogen flows through the lower part.

Metering ports in the plates ensure the uniform distribution of the hydrogen, oxygen, and coolant. Seals molded in the plates prevent leakage. A thin nickel foil 5 mils (0.13 mm) thick separates the oxygen and hydrogen cavities.

This work was done by William F. Bell III, Ronald E. Martin, Albin J. Struning, and Robert Whitehill of International Fuel Cells for **Johnson Space Center.**
MSC-21338/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

NASA's Jet Propulsion Laboratory, Pasadena, California

Choosing Compositions of Electrocatalysts

The best alloys for fuel cells and batteries can be determined from thermodynamical considerations.

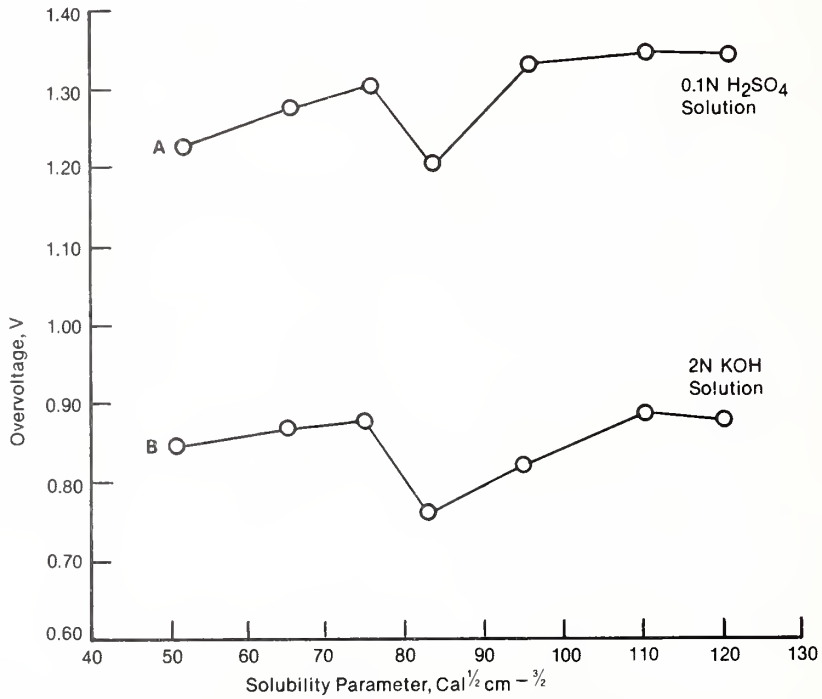
A simple theory predicts the compositions of alloys that exhibit maximum catalytic activities in the presence of certain reactants. The method can be used to select the best catalysts for electrochemical batteries and fuel cells. It predicted, for example, that a platinum/lead electrocatalyst of specified composition would provide the lowest overvoltage of an oxygen electrode in an acidic or basic medium in a lithium battery. This prediction was borne out by experiment.

The method is based on one used to analyze the activities of nonelectrical catalysts in reactions involving hydrogen or oxygen. The rate of such a reaction increases when the solubility parameter of the catalyst matches that of the reactant.

The only difference between a catalyst and an electrocatalyst is that the latter must also be a good conductor of electrons and be chemically stable in the electrochemical environment in which it is to be used. Accordingly, it seemed that the effectiveness of electrocatalysts in metallic solutions could be calculated from thermodynamic relationships that describe the formation of solid solutions, in combination with models for the appropriate solutions.

From such calculations, three alloys appeared promising: lead/platinum, gold/silver, and silver/palladium. Of these, the lead/platinum system had previously shown high activity in anodic oxidation in an ethylene glycol fuel cell.

Accordingly, lead/platinum was selected for experimental evaluation. The electrochemical electrode overvoltage was measured as a function of the solubility parameter (see figure). The lower the overvoltage, the more efficient the electrocatalytic kinetics are. For lead/platinum, the lowest overvoltage occurred for a solubility parameter of about 83 $cal^{1/2}\ cm^{-3/2}$ — a value close to that of atomic oxygen, as would be expected in nonelectrical catalysis. This solubility parameter represents an electrode composed of about 54 percent lead and 46 percent platinum by volume.



The **Oxygen-Electrode Overvoltage** is plotted against the solubility parameter of a lead/platinum electrode in acidic (upper curve) and basic (lower curve) solutions. The electrode was formed by plating mixtures of lead and platinum, corresponding to various solubility parameters.

This work was done by Daniel D. Lawson of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17167/TN.

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NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

New Device Saves Electronic Components

A new instrument that non-destructively tests electronic switching components has been developed by David W. Berning, a NIST electronics engineer. The instrument - an automated power transistor switching test system - determines the maximum voltage and current levels that the device under test can switch without destroying it. The idea behind the new instrument is that the temperature rise which actually destroys the transistor, or other power electronic device, occurs slightly after the electrical breakdown of the device. The breakdown occurs when the electric current reaches a point where the device can no longer stand the voltage in the circuit. The trick is to remove the power before the device heats up enough to be damaged. Knowing the performance limits of transistors can reduce a user's costs because users often make their transistor specifications more stringent than necessary to ensure system reliability. Power transistors are vital components in control systems for applications ranging from the main engines of the space shuttle to your automobile. They are essential to electronic amplifiers, modern switching power supplies, and electric motor drives.

FOR ADDITIONAL INFORMATION: Media contact is John Makulowich (301)975-2762. To discuss these efforts further, contact, David Berning, Technology Building, Room B310, National Institute of Standards & Technology, Gaithersburg, MD 20899; (301)975-2069.

Engineering

1032 Equation Developed for Predicting Steels in Fire

1033 Modern Electronic Offices can be Major Fire Hazard

1034 Quick Way to Measure Heat Conduction

1035 Vaporizer for Low Vapor Pressure Gases (Licensing Opportunity)

1036 Advanced Engraving of Angle-Encoder Disks (Licensing Opportunity)

1037 Algorithm for Optimal Control of Large Structures

1038 Capillary-Condenser-Pumped Heat-Transfer Loop (Licensing Opportunity)

1039 Attaching Precise Mirrors to Lightweight Supports

1040 Calculating Flows in Turbomachine Channels

1041 Cleanly Burning Squib

1042 Electrostatic Spraying with Conductive Liquids (Licensing Opportunity)

1043 Energy-Efficient, Continuous-Flow Ash Lockhopper (Licensing Opportunity)

1044 Fluidized-Bed Reactor with Zone Heating

1045 Improved Flow-Controlling Vortex Generator (Licensing Opportunity)

Software

1046 "Hazard I" Released to Help Reduce Fire Deaths and Costs

Testing & Instrumentation

1047 New Acoustic Detection System Developed (Licensing Opportunity)

1048 Discriminating Fire Detector

1049 Fluidic Capillary Pyrometer

1050 Fluidic Pressure Regulator

1051 Opto-Fluidic Interface

1052 Spring-Blade Impact Tester

1053 Automated Heat-Flux-Calibration Facility

Other Items of Interest

1009 Ideal Resampling of Discrete Sequences—Spectral information is preserved to the extent possible.

1021 Computer-Aided Engineering of Cabling—This program generates data sheets, drawings, and other information on electrical connections.

1054 Power Plant Scrubbers Now Remove Nitrogen Oxides

1057 Linear Coal Cutting Concept Reduces Respirable Dust Generation and Provides Larger, More Uniform Product

1059 Inversion of Jacobian Matrix for Robot Manipulators—A closed-form transformation from task space to joint space is computed efficiently.

085 Computer Program for Detecting or Predicting Fracture Zones

1089 Enzyme Work Increases Industry Profits

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Equation Developed for Predicting Steels in Fire

NIST scientists have developed an equation for predicting the performance of ASTM A36 structural steel during and after a fire. Designed for personal computers (PCs), the equation predicts the performance of the most commonly used steel in the United States when the material is exposed to fire for periods from 2 minutes to 8 hours over a temperature range from 350 to 650 degrees Celsius. To assess deformation, an analysis of the various stresses, temperatures, and times involved are required in order to calculate the resulting strains. Each type of strain - elastic, recoverable; plastic, time-independent; and creep, time-dependent - has its own formula. The equation also can be used to construct "deformation mechanism" maps to show the dominant behavior of steel at any given time, temperature, and stress, and to compare the performance of A36 to foreign steels.

FOR ADDITIONAL INFORMATION: A report, Elevated Temperature Deformation of Structural Steel (NISTIR 88-3899), with the new equation and information on the correlations between measured and produced strains for ASTM A36, Australian AS A149, and Japanese SS41 structural steel steels, is available from the National Technical Information Service, Springfield, VA. 22161; (703)487-4600.

NTIS order number: PB89-172621/NAC
Price code: A06

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Modern Electronic Offices can be Major Fire Hazard

Open offices densely packed with electronic equipment - such as personal computers and monitors and extensive wiring systems - as well as large amounts of paper and office furniture, constitute a major fire hazard, say NIST researchers in a study of the May 1988 fire in the First Interstate Bank Building in Los Angeles. The late evening fire spread from the 12th to 16th floors of the 62-story building with damage estimated at hundreds of millions of dollars.. One person was killed. Using computer models to reconstruct the fire, the researchers determined that approximately 11 minutes after the fire started two events occurred almost simultaneously - the first window broke and the room "flashed over." This started a cycle in which air from the broken window enabled the fire to grow, breaking more windows, and so on. Not only did the broken windows feed air to the fire but they served as a means of fire spread, found the NIST researchers. The computer analysis also showed that if the fire had burned longer or had spread faster from floor to floor, it may have been unstoppable.

FOR ADDITIONAL INFORMATION: A report, An Engineering View of the Fire of May 4, 1988, in the First Interstate Bank, Los Angeles, California (NISTIR 89-4061), is available from the National Technical Information Service, Springfield, Va. 22161; (703)487-4600.

NTIS order number: PB89-183222NAC
Price code: A03

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Quick Way to Measure Heat Conduction

Researchers from the NIST Center for Building Technology and the Virginia Polytechnic Institute and State University have investigated a quick technique for measuring on-site the heat-conducting properties of building insulation materials. Generally, this information is obtained through laboratory testing. Once in place, however, the material can settle or accumulate moisture and lose some of its insulation value. The new technique uses a thermistor, a semiconductor device, as a probe along with a computer which controls the system and gathers data. Once inserted into the insulation, the probe acts both as a heater and a sensor to measure how the heat is being dissipated through the insulation over time. While the technique does have advantages, it also has limitations - primarily, a lack of suitable calibration materials.

FOR ADDITIONAL INFORMATION: Development of an Automated Probe for Thermal Conductivity Measurements (NIST-GCR-89-563), is available from the National Technical Information Service, Springfield, Va. 22161: (703)487-4600.

NTIS order number: PB89-209324NAC
Price code: A07

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Vaporizer for Low Vapor Pressure Gases

A vaporizer to convert liquid dinitrogen tetroxide to gaseous nitrogen dioxide was designed to work as an attachment to the supply cylinder. The device heats aliquots from the cylinder, maintains and monitors temperature and pressure of the aliquots, and provides a constant supply of gaseous nitrogen dioxide. Parallel aliquot units allow using one as a supply while the other is being refilled. The unit is equipped with a pressure relief valve. The device avoids the method of heating the whole supply cylinder which could blow off the cylinder head if overheated. The vaporizer improves existing technology because small aliquots of dinitrogen tetroxide are heated, avoiding power demands and safety related issues of heating the entire supply cylinder. The device has application as a generic vaporizer for low vapor pressure gases which need to be heated at ambient conditions.

FOR ADDITIONAL INFORMATION: Contact Robert R. Campbell, Idaho National Engineering Laboratory, P. O. Box 4000, Idaho Falls, ID 83403; (208)526-0997. Refer to DOE/INEL-046/TN.

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Advanced Engraving of Angle-Encoder Disks

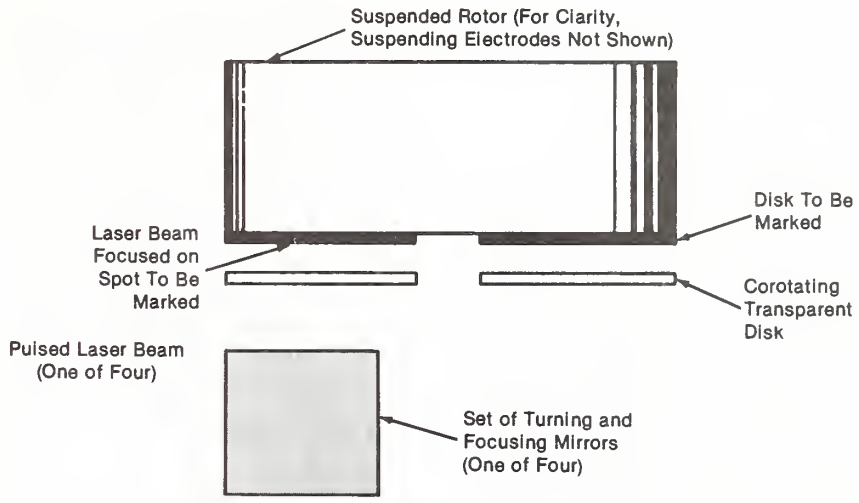
Precision would be increased over that of mechanical engravers.

A proposed optical/mechanical/electronic system would engrave the angular-interval marks on angle-encoder disks. The system was conceived to meet the need for increased precision of angular measurements in advanced scientific instruments.

At present, the most-precise angular-encoder disks are made on mechanical angle-dividing machines. Small increases in the precision of such machines are expensive and consume much time. The proposed system would abandon the traditional mechanical-precision approach, relying instead on a combination of the high precision of electronic time division and digital synthesis of frequency with the almost-friction-free motion of a rotor suspended in a high vacuum by electrostatic forces.

As shown schematically in the figure, the disk to be engraved would be mounted on the lower end of a short cylindrical rotor suspended electrostatically and would serve as the lower-end rotor electrode. Voltages applied to all the electrodes of the electrostatic suspension system would be determined by a feedback control subsystem that would sense the various capacitances between the end and side rotor and stator electrodes. Because these capacitances depend on the position and orientation of the rotor relative to the stator, the subsystem could process the capacitance signals to compensate for asymmetry in the rotor, seismicity, and other perturbations in such a way as to keep the axis of the rotor vertical and at the desired position.

The surface of the disk to be engraved would be coated with a noble metal. Focused laser beams would mark this surface by evaporating the metal at the designated spots. There would be two pairs of laser beams, arranged orthogonally to enable cancellation of the effects of deviations of the lateral position of the rotor. For equal angular increments, the lasers would be pulsed periodically, at intervals of the fraction of the period of rotation corresponding to the desired increment of angle.


Suspended Rotor (For Clarity, Suspending Electrodes Not Shown)
Disk To Be Marked
Laser Beam Focused on Spot To Be Marked
Corotating Transparent Disk
Pulsed Laser Beam (One of Four)
Set of Turning and Focusing Mirrors (One of Four)

Laser Pulses Timed According to the Rotational Speed of a rotor electrostatically suspended in a vacuum would mark an angular-encoder disk mounted on the lower end of the rotor. The precision of the timing circuitry and the low rotational damping (damping time about 700 years in a high vacuum) would result in highly-precise angular intervals.

A corotating (but normally mechanically-separate) transparent disk below the disk to be engraved would collect the evaporated metal so that it does not accumulate on the laser-beam windows, where it would otherwise subsequently attenuate the laser beams. To bring the rotor up to the desired rate of rotation, the corotating disk would initially be connected to the rotor via a piezoelectric or electromagnetic clutch, which would disengage when the rotor attains the desired speed.

The pressure of the metal vapor and the electric field in the interelectrode gaps must be kept below the levels that would trigger electrical arcs. Preferably, the voltages applied to the top and side electrodes would be balanced in such a way that the electric field at the bottom disk could be zero. Alternatively, the suspension voltages could be interrupted in synchronism with the laser pulses to prevent arcing, but this would necessitate the careful avoidance of harmonics to prevent excessive vibrations.

This work was done by Walter K. Polstorff of **Marshall Space Flight Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel. Marshall Space Flight Center. Refer to MSC-28294/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Algorithm for Optimal Control of Large Structures

The cost of computation appears competitive with that of other methods.

An iterative algorithm has been derived for the numerical computation of optimal control of a linear system (e.g., a large, vibrating structure) of many degrees of freedom. The cost of the algorithm, as measured in terms of the number of computations required, is of the order of, or less than, the cost of prior algorithms applied to similar problems.

The problem is to compute the optimal control of forced response of a structure with n degrees of freedom that is identified in terms of a smaller number, r, of vibrational modes. The article begins with the Hamilton-Jacobi formulation of mechanics and the use of a quadratic cost functional. While the Hamilton-Jacobi approach has previously resulted in computational complexity that increased almost exponentially with n, the complexity can be reduced by an alternative approach in which the quadratic cost functional is expressed in terms of the control variables only. This leads to the iterative solution of a second-order time-integral matrix Volterra equation of the second kind that contains the optimal control vector.

At each iteration, the matrix Volterra equation is integrated numerically by use of a trapezoidal integration scheme in which the control interval is discretized into s equally spaced intervals of time. The particular structure of the matrices can be exploited to reduce the number of computations and to enable the use of a Jacobi-type iterative solution. Some steps are common to all iterations and thus need to be executed only once.

Overall, the total number of computations required is of the order of

$$[4r(q_{max}+r)ms+n^2]$$

where m is the number of control variables and q_{max} is the number of iterations required for convergence. Although q_{max} is not known a priori, the dominance of diagonal terms in one of the matrices at an intermediate step of the derivation suggests that q_{max} should be of the order of 10. As a result, the algorithm appears to be competitive with other methods based on solutions to matrix Riccati equations, especially at large n.

This work was done by Moktar A. Salama and John A. Garba of Caltech and Senol Utku of Duke University for **NASA's Jet Propulsion Laboratory**.

NPO-16983/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Capillary-Condenser-Pumped Heat-Transfer Loop

The heat being transferred supplies the operating power.

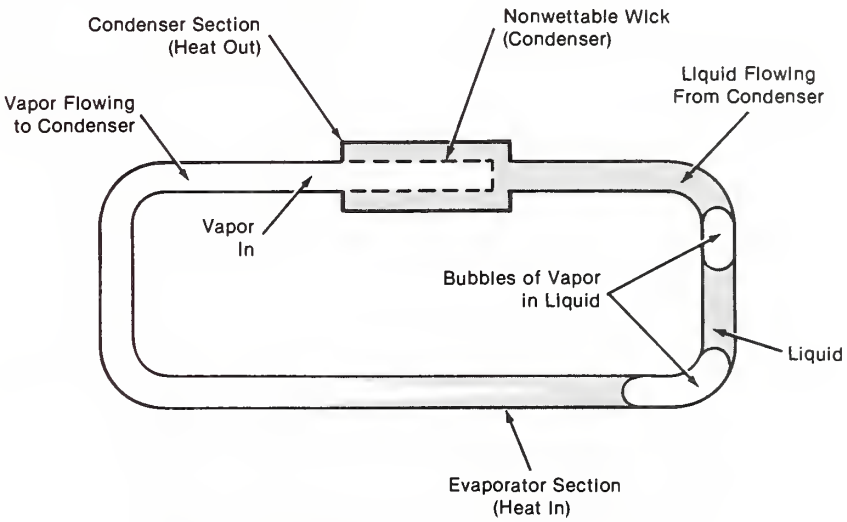
The capillary-condenser-pumped loop is a closed-circuit, two-phase-fluid system for the transfer of heat through relatively long pipes. Like a heat pipe, this system requires no pump or externally supplied power to circulate the heat-transfer fluid, relying instead on the flow of heat in its evaporator and condenser sections to do the pumping. Unlike in a heat pipe, in which the liquid and vapor flow in opposite directions, the liquid and vapor in the capillary-condenser-pumped loop flow in the same direction.

In some respects, the capillary-condenser-pumped loop is essentially a capillary-evaporator-pumped loop operating in reverse. The loop (see figure) is filled with the fluid in both liquid and vapor phases. Heat is added to the liquid phase along the evaporator section (an ordinary pipe with no wick structure), causing the liquid to vaporize. Heat is removed in the relatively short condenser section, causing the vapor to condense.

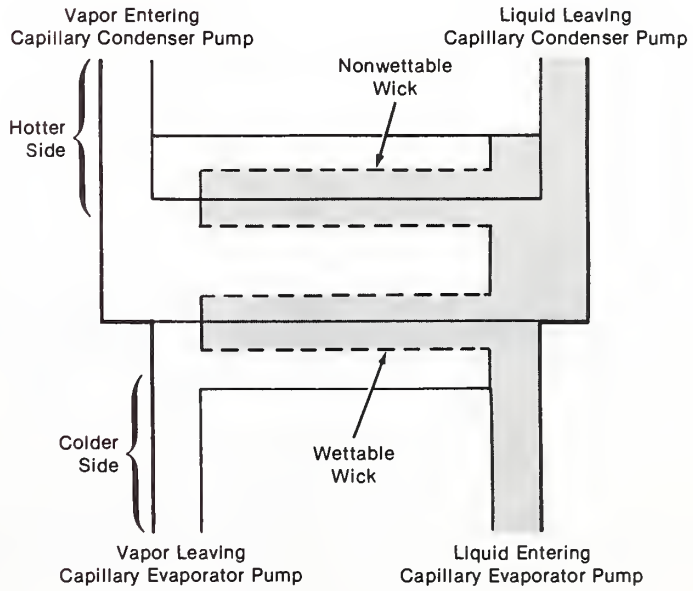
The condenser section contains a nonwettable, porous wick structure in thermal contact with an external heat sink. (The corresponding section of a capillary evaporator pump would contain a porous, wettable wick.) The pressure is at a minimum in the vapor condensing in the wick and at a maximum in the liquid that has just condensed. The capillary pressure due to the surface tension of the liquid in the wick is the source of this difference in pressure and balances the pressure lost in pumping the fluid around the loop. The pressure in the condensed liquid pushes this liquid out of the condenser, causing the fluid to flow once again around the loop.

Whereas a capillary evaporator pump must be placed at a heat source, the capillary condenser pump can be placed at a heat sink. Thus, a capillary-condenser-pump heat-transfer loop is preferable where the heat-input (evaporator) length is greater than the available heat-rejection (condenser) length. This situation exists, for example, where the surface of a hypersonic airplane has to be cooled by transporting the aerodynamically generated heat to a central hydrogen-fuel heat sink.

The capillary-condenser-pumped loop



CAPILLARY-CONDENSER-PUMPED HEAT-TRANSFER LOOP



HEAT EXCHANGER

The **Capillary-Condenser-Pumped Heat-Transfer Loop** is similar to a heat pipe and to a capillary-evaporator-pumped heat-transfer loop in that the heat-transfer fluid is pumped by the evaporation and condensation of the fluid at the heat source and sink, respectively. A capillary condenser pump can be combined with a capillary evaporator pump (below) to form a heat exchanger that circulates the heat-transfer fluids in both loops.

offers the following additional advantages:

- Because only a small fraction of the loop is filled with liquid, the weight is lower than that of a forced-convection loop, which must be filled completely.
- The internal pressure is limited to the saturation pressure of the heat-transfer fluid, whereas in an all-liquid forced-convection system, the internal pressure may be several times as high. The lower internal pressure may permit the use of thinner tubing, thus reducing weight even further.
- The transport of heat is more nearly isothermal than in older heat-transport systems of similar capacity. Thus, thermal stress in the loop is reduced, and less external surface area is needed in the condenser section for the rejection of heat to the heat sink.

This work was done by Calvin C. Silverstein of CCS Associates for **Marshall Space Fight Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-26046/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Attaching Precise Mirrors to Lightweight Supports

Mirrors would be formed on optical masters and glued in place.

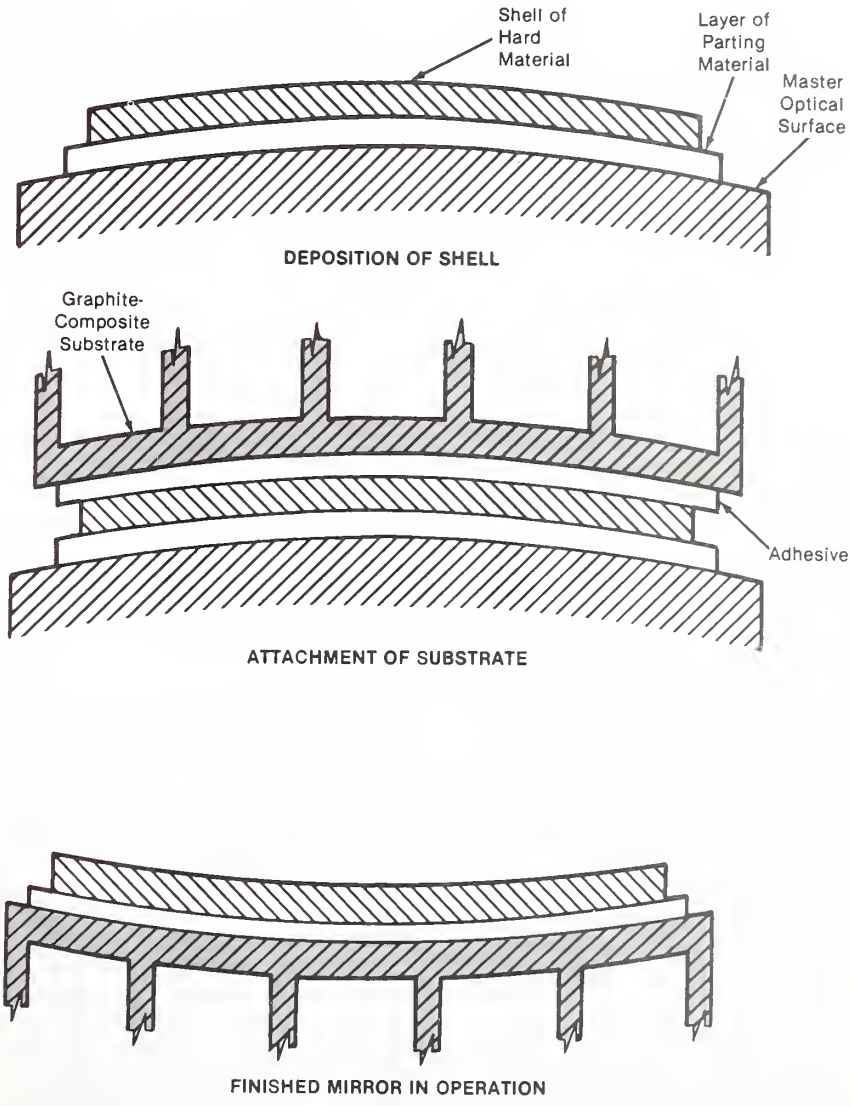
A technique has been proposed to form precise mirror surfaces on lightweight, rigid, imprecise graphite-composite substrates. The technique should enable the fabrication of lightweight mirrors of high surface finish suitable for use at short wavelengths: Heretofore, the irreducible small-scale roughness of the surfaces due to the structures of composite materials inhibited the use of composite mirrors at short wavelengths.

The technique (see figure) resembles that used to make lightweight replica mirrors and gratings. A layer of parting material is deposited on a master optical surface of the precise desired shape. This parting layer must be very thin to minimize degradation of the replica.

By ion-assisted evaporation or another established method, a shell of mirror or mirror-supporting material is deposited on the parting layer. The shell could be made of SiO_2, SiN, HfN, or other hard material. The thickness of the shell is made large enough — typically between a few microns and 1 mm — to give the shell significant rigidity of its own and to withstand handling and abrasion.

Next, a layer of adhesive much thinner than the shell is used to attach the mirror shell to a graphite-composite substrate, the surface of which approximates the desired mirror surface. When the adhesive has cured, the substrate and shell are separated from the master at the parting layer. The resulting mirror has nearly the high optical quality of the master.

This work was done by Aden B. Meinel and Marjorie P. Meinel of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17164/TN*



A **Mirror Would Be Attached** to an imprecise substrate in a procedure similar to that used to make replica mirrors and gratings.

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Calculating Flows in Turbomachine Channels

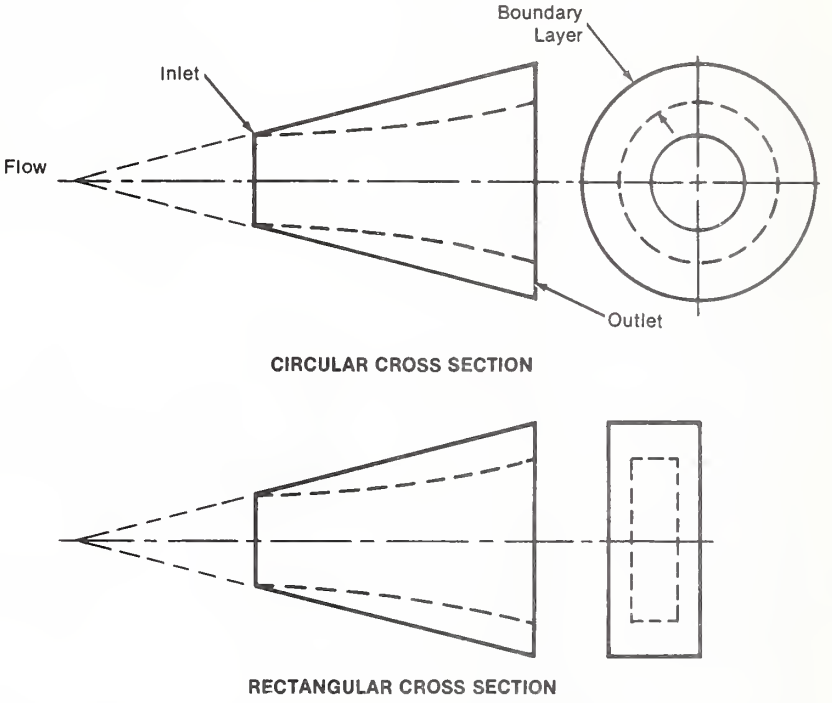
A noniterative integral-entrainment method yields good approximations.

A method of approximate calculation of flow in a channel of a turbomachine is based on the interaction of viscous flow in the boundary layers with inviscid flow in the core layer. The method is both faster and more robust than other approximate methods of the same type. The method is suitable for use in preliminary calculations for design and for off-design operation of turbomachinery.

The method involves the following assumptions:

1. The flow is turbulent everywhere but in other respects can be treated as though it were steady everywhere.
2. The fluid is a perfect gas.
3. The flow in the boundary layers is two-dimensional, without a crossflow component.
4. The flow surfaces are adiabatic.
5. Density varies along the streamlines but not along lines perpendicular to the boundaries.
6. The streamline velocity in the boundary layer is describable by a simple power-law equation in the distance from the wall, the thickness of the layer, and the velocity at the edge of the boundary layer, which is taken to be the free-stream velocity.
7. The flow in the core can be treated as though it were one-dimensional, in the sense that the two-dimensional equations of the conservation of momentum and mass can be reduced to one-dimensional equations in the coordinate along a streamline.

The equations of conservation of momentum and mass are integrated through the boundary layers, and some additional assumptions regarding the geometrical properties of the streamlines are invoked. Head's entrainment relation is introduced to find the perpendicular component of velocity at the edge of the boundary layer. The skin-friction coefficient is obtained from the Ludwig-Tillman relation. The variation of free-stream velocity is determined via the simple one-dimensional equation of continuity for the flow in the core. The set of equations is completed with the energy equation and the equation of state of the flow in the core, which are used to relate the static temperature, pressure, and density to the other quantities.



The Flows in Conical Diffuser Channels are represented by two-dimensional boundary-layer and one-dimensional core flows described by the equations of the new method.

The foregoing constitute a set of simultaneous one-dimensional differential equations that are solved together to find the flow field. Because no iteration is involved, the solution is found rapidly — that is, the integration is performed in one pass along the channel. With some modifications and additional assumptions, the equations can also be solved for flow with merged boundary layers and no isentropic core ("fully developed" flow) and for separated flow.

The method has been applied to round and rectangular conical diffuser channels (see figure). The calculated pressure coefficients and other quantities of interest were in good agreement with experimental values in cases in which the analysis indicated no separation of flow. The pressure coefficients showed fair agreement in the separated regions.

This work was done by Lawrence F. Schumann of the U.S. Army Aviation Research and Technology Activity for **Lewis Research Center**. *Further information may be found in NASA TM-88928 [N87-15944], Price Code A02 "A Method for Calculating Turbulent Boundary Layers and Losses in the Flow Channels of Turbomachines."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14705/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Cleanly Burning Squib

The ignition wire would be repositioned to suppress unburned particles.

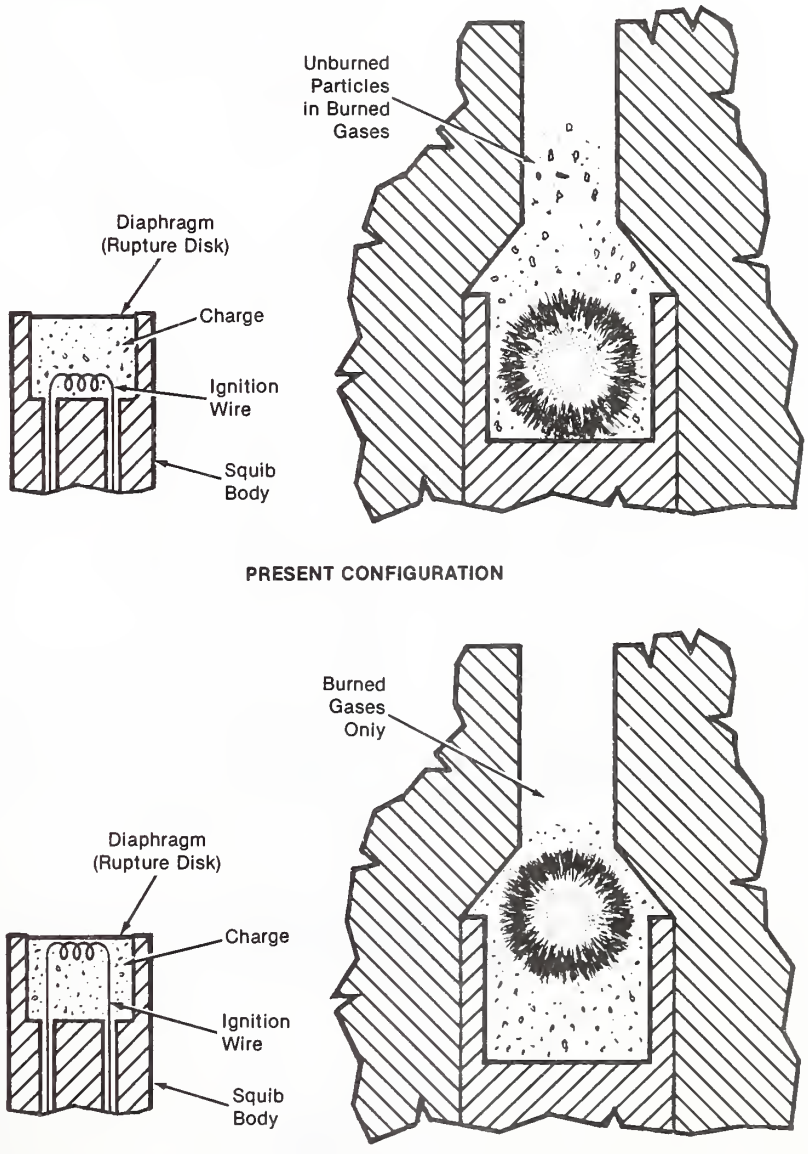
A proposed pyrotechnic squib would burn more thoroughly and cleanly than its predecessors. It would therefore rupture its diaphragm and release its hot gases at a pressure that is more nearly constant and predictable from unit to unit.

In the present version, the ignition wire that ignites the charge is located at the bottom of the combustion chamber (see figure). The charge thus burns upward and can expel unburned particles of the charge, creating localized and unpredictable variations in pressure that affect adversely the operation of the squib-actuated mechanism.

In the proposed new configuration, also shown in the figure, the ignition coil would be located near the top of the combustion chamber. As the charge burns, the unburned portion would be held at the bottom of the chamber. Little or no unburned charge would be ejected. A more nearly uniform pressure would be generated, and only gases would be ejected from the combustion chamber.

This work was done by Donald B. Bickler of Caltech for **NASA's Jet Propulsion Laboratory**.

Refer to NPO-172-17277/TN.



The **Ignition Coil Would Be Moved Upward** from its present position at the base of the combustion chamber. This arrangement would help to contain solid particles of the explosive charge until they are gasified by combustion. In the present configuration, particles can escape before they burn.

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

Electrostatic Spraying With Conductive Liquids

Thin, uniform polymer coatings can be applied in a water base normally impossible to charge.

An electrostatic sprayer has been modified so that it can apply coatings suspended or dissolved in electrically conductive liquids. The sprayer was developed to apply a water-base polyurethane coating to a woven, shaped polyester fabric. The coating provides a pressure seal for the fabric, which is part of a spacesuit. The sprayer may also be useful for applying waterproof, decorative, or protective coatings to fabrics for use on Earth.

Ordinarily, such a sprayer cannot handle water or other conductive liquids because the tip of the nozzle electrode tends to short-circuit; it cannot then impart a charge to the particles in the atomized liquid. In the modified sprayer, the nozzle and gun are constructed of nonconductive molded plastic. The liquid passageway is made long enough that electrical leakage through it is low. The coaxial hose for the liquid is built of a polytetrafluoroethylene tube, an insulating sleeve, and a polyurethane jacket.

In addition, the sprayer is provided with an insulated seal at the gun-to-hose connection, a nonconductive airhose, a pressure tank electrically isolated from ground, and a special nozzle electrode. The supply of atomizing air is reduced so that particle momentum will be controlled by the electrostatic field more effectively.

A high-voltage cable is connected to the nozzle electrode in the spray head. The polyurethane/water mixture passes from a pressurized pot through the coaxial hose to the nozzle. There it is atomized by the air supply and charged by the negative nozzle electrode so that it emerges from the gun as a spray of uniformly dispersed negative particles. A nozzle voltage of more than 30 kV is needed.

The fabric is not conductive enough to act as a positive electrode. It is therefore placed on a metal plate shaped to conform with the fabric. The electrostatic field passes directly through the thin fabric, setting up a force field perpendicular to the surface of the grounded plate. The fabric interstices thus become thoroughly filled, since the charged particles try to penetrate the fabric. Even irregularly shaped surfaces become smoothly and uniformly coated.

As a precaution, the fabric surface should be made thoroughly clean, as should the atmosphere in which the spraying process is carried out. Otherwise, dirt particles on the fabric will align with the force field and stand upright, creating a flocked surface.

This work was done by Joseph J. Kosmo and Frederic S. Dawn of **Johnson Space Center** *and Robert E. Erlandson and Loren E. Atkins of Albany International Research Co. For further information, Circle 85 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to the Albany International Research Co. Inquiries concerning licenses for its commercial development should be addressed to

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1000 Providence Highway
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Energy-Efficient, Continuous-Flow Ash Lockhopper

Pressure balance in the control gas prevents the loss of reactor gas.

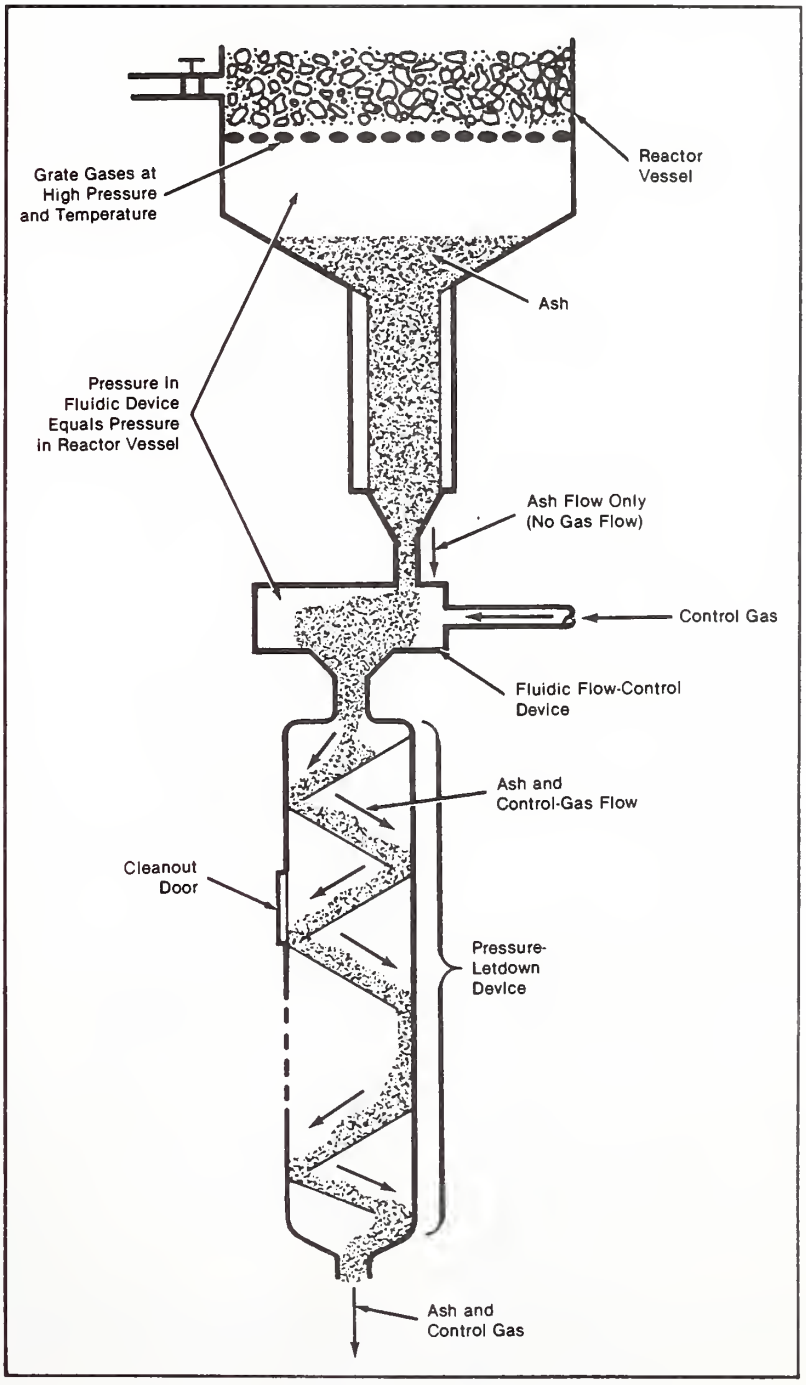
The energy efficiency of a continuous-flow ash lockhopper (see figure) has been increased by preventing hot gases from flowing out of a reactor vessel through the ash-hopper outlet and carrying away heat energy. Stopping the loss of reactor gases can also be important for reasons other than energy efficiency: the desired reaction product may be a gas, or the gases produced may be toxic or may need to be contained to prevent pollution. The improved lockhopper should also enable the reactor to attain the highest possible product yield with continuous processing while permitting a controllable, continuous flow of ash.

The principal components of the lockhopper have been discussed in the following NASA Tech Briefs: "Pressure-Letdown Plates for Coal Gasifiers" (NPO-15965), page 355, Vol. 8, No. 3 and "Variable Control Part for Fluidic Control Device" (NPO-16603), page 114, Vol. 10, No. 2. The lockhopper was designed to convert reactor solids removal from batch to continuous flow; it should also be applicable in fluidized-bed reactor systems and in the separation of dust or other solids from gases.

In the improved lockhopper, the loss of the reactor gas is prevented by equalization of the pressure of the control gas injected into the fluidic flow-control device with the pressure in the reactor vessel. This eliminates the pressure gradient at the ash outlet of the reactor. However, the flow of ash continues because of gravity. In scale-model tests that used sand to simulate ash, the continuous flow of the sand was obtained without loss of reactor pressure.

In the original lockhopper, a quasi-porous-plug pressure-letdown device greatly reduced, but did not eliminate, the loss of gas and the concomitant loss of heat from the reactor vessel. In the improved lockhopper, the pressure-letdown device serves to reduce the flow of control gas required to achieve the equalization of pressures.

The original lockhopper used steam as the control gas, but in some processes the introduction of steam into the reactor vessel is not permissible or not desirable. The steam was generated by injecting water in-



In the **Improved Continuous-Flow Ash Lockhopper**, the pressure-driven loss of hot gas from the reactor vessel through the ash-hopper outlet is prevented by using the control gas in the fluidic flow-control device to equalize the pressure in the reactor vesel.

to the ash-hopper outlet of the reactor. This quench water also caused large cinders to disintegrate into fine ash that could pass through the fluidic control and pressure-letdown devices. With the improved lock-hopper, moving grates or other conventional mechanical methods would be used to break up cinders when necessary.

In many applications the control gas may be compressed air; in others, inert gases or other specific gases may be required. The control gas eventually leaves the system along with the ash, but a collecting chamber with scavenging compressor pumps can be used to recover it for recirculation.

This work was done by Earl R. Collins, Jr. and Jerry W. Suitor of Caltech **NASA's Jet Propulsion Laboratory** *and David Dubis of the Morgantown Energy Technology Center of the Department of Energy.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-16985/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Fluidized-Bed Reactor With Zone Heating

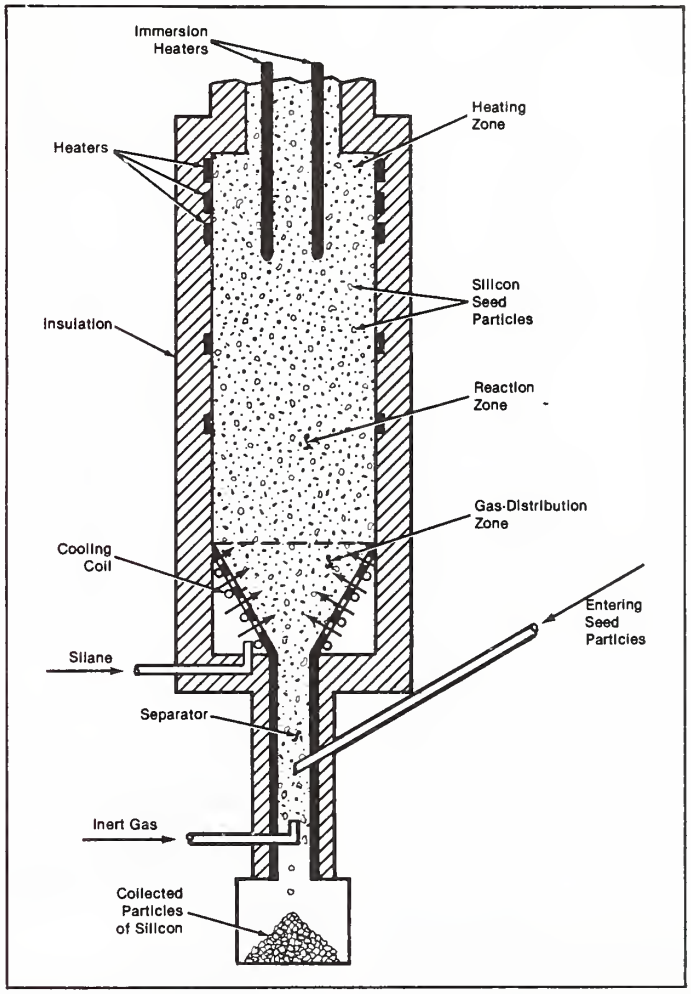
Deposition of silicon on the wall is suppressed.

The design of a fluidized bed for production of silicon greatly reduces the tendency of silicon to deposit on the wall of the reaction vessel. In the new fluidized bed, the silicon seed particles are heated in the uppermost zone of the reactor. The hot particles gradually mix with the lower particles and descend through the fluidized bed. The lower wall of the vessel is kept relatively cool. Because silane that enters at the bottom and circulates through the reactor is pyrolized to silicon at high temperatures, silicon is therefore deposited on the particles in preference to the wall.

A typical previous fluidized bed, in contrast, was heated through the wall. Therefore, the wall was hotter than the reaction zone, and silicon was deposited on the wall as well as on the bed particles, reducing the net yield of silicon and creating a clean-up problem. Moreover, the high temperature in the lower layers of the bed favored the formation of fine silicon dust that had to be separated from the product particles and recovered.

In the new process, silicon seed particles are introduced into the base of the reactor vessel (see figure), where a stream of inert gas creates a fluidized bed of the particles extending almost to the top of the vessel. At the top of the bed, immersion heaters encased in quartz and wall heaters maintain a temperature of 650 to 800 °C. The turbulence of the bed mixes hot seed particles from the heating zone with particles in lower layers, the net result being a vertical gradient of temperature ranging down to 450 to 650 °C at the bottom of the bed. Wall heaters add only enough heat to make up for losses.

Silane flowing up from the base of the vessel decomposes in the reaction zone just below the heating zone, depositing silicon on the silicon seed particles but not on the wall. Essentially all the silane reacts in the reaction zone; it does not flow into the heating zone. Once a particle has grown to a size of 400 to 1,500 μm, the particle descends from the reaction zone through a separator to a collector.



The **Upper Heating Zone** furnishes about 80 percent of the heat for the pyrolysis of silane. The temperature in the reactor ranges from about 700 °C at its top to about 300 °C at the silane-gas distributor at its bottom. Polycrystalline silicon particles fall through the fluidized bed and are collected at the bottom.

Silane enters the vessel through a perforated distributor cone at the bottom. Water circulating in a coil around the distributor cone keeps it at a temperature of about 300 °C — low enough to suppress the deposition of silicon dust even though the silane is highly concentrated at this point in the reactor.

In a demonstration of the process, about 8 kW of power were supplied to the top 15 in. (38 cm), and 2 kW were supplied to the remainder of a reactor 72 in. (183 cm) high and 6 in. (15.2 cm) in diameter. The reactor yielded 1 kg of silicon per hour. The ratio of this rate of yield to input power (0.1 g/Wh) is about 30 times that of a commonly-used batch process and may be higher than that of other fluidized-bed processes as well.

This work was done by Sridhar K. Iya of Union Carbide Corp. for **NASA's Jet Propulsion Laboratory**. *NPO-17470/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved Flow-Controlling Vortex Generator

Symmetrical tangential streams control flow of radial primary streams.

A vortex generator uses a small secondary stream of fluid to control a normally-larger primary stream. The device is an improved version of the vortex generator described in "Variable Control Port for Fluidic Control Device," (NPO-16603), *NASA Tech Briefs*, Vol. 10, No. 2 (March/April 1986), pp. 114-115. Like a valve, the vortex generator can vary the rate of flow of the primary fluid from its maximum value down to zero. When properly designed, it requires a low pressure differential between the primary and secondary streams and expends a relatively small amount of secondary fluid.

The vortex generator consists of a disk-like short, hollow cylinder in which the primary fluid enters radially at two opposed points while two secondary streams enter tangentially at points 90° from the primary streams (see figure). An exit port is located at the center of one end of the cylinder.

The primary fluid enters through slots that extend the height of the cylinder. Without any secondary flow, the primary streams flow directly from their entrance ports to the central exit port. When the secondary streams are introduced (at a smaller volume and greater velocity), they set up a circular flow that gradually spirals inward to the exit port.

The rotating fluid exerts pressure against the periphery of the cylinder in proportion to the square of the circumferential velocity of the fluid and inversely proportional to the radius of the cylinder. This centrifugal pressure acts against the primary-fluid inlet ports as well as against the wall. Thus, the greater the speed of the secondary fluid, the smaller the flow from the primary inlet ports. When the centrifugal pressure equals the primary inlet pressure, the primary flow stops. At that point, the only fluid leaving the exit port is the secondary fluid.

In an experimental version of the valve with air as the fluid, a secondary pressure of only 100 psi (0.69 MPa) created enough circumferential flow to cut off the primary flow at a supply pressure of 80 psi (0.55 MPa). The secondary flow aids in removing particles previously entrained in the primary flow that have been dropped in the vortex generator. In tests with combinations of air and sand; water and sand; air, water, and sand; and diesel fuel, n-pentane gas, and pulverized coal; the secondary gas (air) swept up the particles and carried them to the exit port.

This work was done by Earl R. Collins, Jr., Wilbur J. Marner, and Naresh K. Rohatgi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 151 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17277, volume and number of this NASA Tech Briefs *issue, and the page number.*

Jet Propulsion Lab.
NASA Resident Office
Technology Utilization Officer: Gordon S. Chapman
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4800 Oak Grove Drive
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Patent Counsel: Paul F. McCaul
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Technology Utilization Mgr. for JPL: Norman L. Chalfin
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Pasadena, CA 91109
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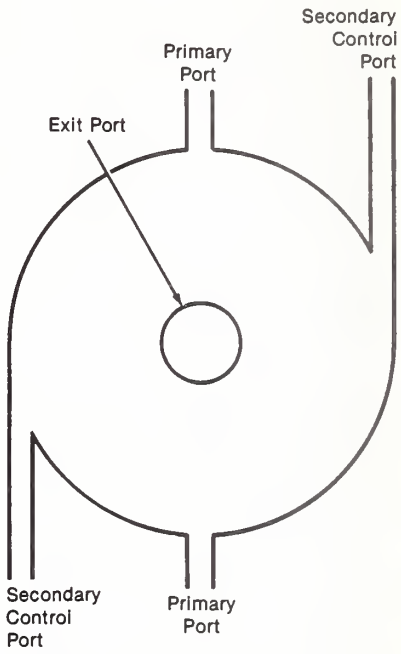

Secondary, or Control, Flows entering tangentially through diametrically opposite ports set up a swirling motion that restrains the primary flow. The pressure of the secondary fluid in relation to that of the primary fluid is the controlling factor.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NIST Technology Update

Software

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

"Hazard I" Released to Help Reduce Fire Deaths and Costs

NIST last week released HAZARD I, a unique analysis method and computer program that promises to revolutionize fire safety practices and lead to marked reductions in fire losses and costs. HAZARD I can be used on a personal computer to predict the hazards to occupants in a burning building and the relative contribution of products, such as furniture, to those hazards. It is the first such comprehensive use of fire modeling in the world. HAZARD I can be used in a variety of ways in fields ranging from fire investigation and reconstruction and fire protection engineering to those concerned with product development, manufacturing, and marketing and architectural design. Also, it can be used to help building and fire codes officials evaluate new materials or design and construction techniques. A three-volume report and a set of computer disks are available for $225 from the National Fire Protection Association, One Stop Data Shop, Batterymarch Park, Quincy, Mass. 02269 or the National Technical Information Service.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600

NTIS order number: PB 89-215404NAC
$225

U.S. Army Fact Sheet

Licensing Opportunity

New Acoustic Detection System Developed

The U.S. Army's Harry Diamond Laboratories (HDL) has developed a working model of an acoustic detection system that has been tested and subjected to limited evaluation in the field. The system was developed to extend the listening capabilities of the field soldier and can be hand-held, is lightweight, rugged and highly directional. In addition, the system is unaffected by moderate wind. The detection system has a number of applications in the civilian sector including security and surveillance systems.

The system combines acoustic and fluidic technologies to amplify sound waves in the audible range (0 - 4 kHz). There is an ongoing research program to extend the listening bandwidth to beyond 5kHz. Fluidic technology is a fundamentally different method of signal amplification in that it employs fluid dynamic principals to sense, amplify and manipulate the incoming acoustic signals into audible pressure signals. The acoustic sensor system achieves a total amplification of generally 60-70 decibels. Because the system is fluidically-based, it does not require signal processing electronics (with associated batteries) and therefore can be highly mobile. The system in its present configuration has a range of about 250 meters for conversational speech depending upon the terrain, humidity and other environmental operating constraints.

In comparison to an electronically-based system the fluidic detection system has the advantage of a negligible noise floor. As a result, the sensitivity of the fluidic system is superior to currently available electronic acoustic amplification systems. Moreover, the fluidic detection system could be further developed for civilian purposes by linkage of fluidics with recent advances in signal processing techniques.

For additional information, contact:

George Gillespie
Harry Diamond Laboratories, SLCHD-TT
200 Powder Mill Road
Aldelphi, MD 20783-1197
Phone: (301) 394-4210

Discriminating Fire Detector

Objective

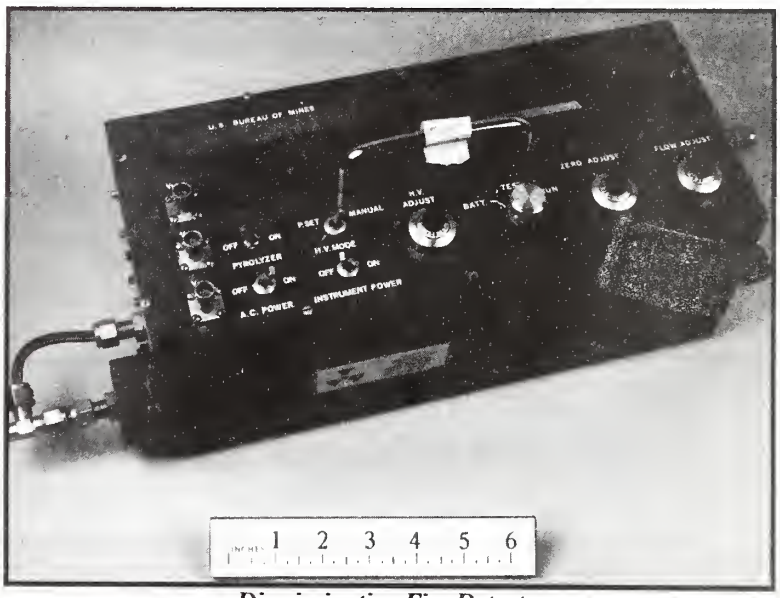
Eliminate the occurrence of false fire detection alarms caused by the operation of diesel-powered vehicles in underground coal mines.

Approach

Fire detection systems used in underground mines are based on measurements of airborne combustion products such as carbon monoxide or smoke particles. The effectiveness and credibility of these systems can be reduced by the occurrence of false alarms that result from the operation of diesel-powered equipment, which produces the same combustion products. False alarms end up being very costly to the mine operation in terms of downtime and labor needed for verification. To improve upon current fire detection systems used in the presence of internal combustion engine products, the U.S. Bureau of Mines developed a fire detector that can discriminate between the occurrence of real mine fires and the presence of engine smoke.

How It Works

Research has shown that fire smoke particles multiply when heated to 300oC, but particulates from internal combustion engines do not. Internal combustion engine products are generated at much higher temperatures than most fire smoke particles. Using this principle, the Bureau's discriminating smoke detector was developed. The detector contains two ionization smoke detection chambers whose outputs



Discriminating Fire Detector

are connected in parallel. When operated, half of the smoke to be sampled is diverted into one chamber while the other half passes through a heated tube before entering the second chamber. If only smoke from an internal combustion engine is present, the output signals from the two chambers are equal and cancel out each other. If only fire smoke is present, the signal from the heated chamber is far different than the signal from the unheated chamber. The

imbalance of signals results in an alarm. When both fire smoke and internal combustion engine smoke are present, an alarm is also sounded because the signal components associated with the engine smoke are canceled. In this way, the fire detector provides reliable fire warning in the presence of products from internal combustion engines, thus advancing the state-of-the-art in fire detection systems.

Test Results

A prototype detector has been extensively tested by the U.S. Bureau of Mines. During these tests, the detector was subjected to fire smokes from a wide range of mine combustibles, both without diesel smoke present in the ventilation airflow. The results showed that the diesel smoke had no effect upon the detector's response to the smoke from the fires. Typical data from these tests indicated alarm conditions at carbon monoxide levels well below 10 ppm. When subjected to diesel smoke only, the detector did not respond.

The detector is presently undergoing in-mine tests and evaluation at an operating coal mine that uses diesel-powered equipment. The Bureau is actively seeking potential manufacturers for this detector. Interested persons or companies should contact Donald E. Ralston, Chief, Office of Technology Transfer, U.S. Bureau of Mines, 2401 E Street, NW., M.S. 6201, Washington, DC 20241 or telephone: (202) 634-1224.

Patent Status

The U.S. Department of the Interior has not applied for a patent on the discriminating fire detector.

For More Information

Additional information or answers to technical questions may be obtained by contacting the Bureau's principal researcher for this development:

Charles D. Litton
U.S. Bureau of Mines
Pittsburgh Research Center
P.O. Box 18070
Cochrans Mill Road
Pittsburgh, PA 15236
Tel: (412) 892-6752

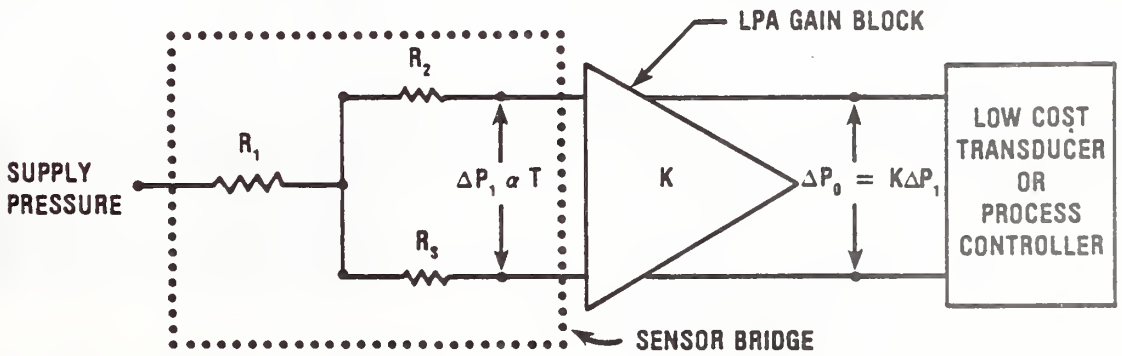
U.S. Army Fact Sheet

Fluidic Capillary Pyrometer

Fluid temperature sensing concepts date back to the beginning of fluidics. The most recent and potentially most promising of these sensors is the fluidic capillary pyrometer (FCP) that is designed to measure temperatures up to the melting points of tungsten in the neighborhood of 3000°C.

The principle of operation for the FCP is analogous to the operation of an electronic resistance thermometer. The temperature-sensitive resistor of the FCP is a capillary tube. A small flow of air (or any gas) is maintained through the tube. The fluidic resistance of the capillary is directly proportional to fluid viscosity, which, in turn, is a function of temperature. If heat is applied to the capillary, the capillary resistances will change, yielding a bridge pressure output as a function of temperature. Typically, this pressure change is quite small, making conventional transduction impractical. Recently, however, a fluidic laminar proportional amplifier (LPA) has been developed that is capable of amplifying very small signals up to usable levels. The amplified bridge pressure output may then be read on a pressure gage, an inexpensive electronic pressure transducer, or interfaced into a control system.

The operating circuit for the FCP is shown schematically in figure 1. Resistor R_1 determines bridge pressure and hence the bridge gain, and resistor R_2 balances the bridge to a desired set point or operating range.



R_1 AND R_2 ARE TRIM RESISTORS

R_S IS A TEMPERATURE-SENSITIVE RESISTOR

Figure 1. FCP schematic diagram.

The FCP offers several distinct advantages over its electronic counterparts for the measurement of high temperatures in hostile environments, especially the high RF environments found in induction and arc furnaces. The sensing phenomenon for the FCP is independent of the sensor material. This feature allows maximum use temperature to be limited only by a structural material. Refractory materials, particularly the oxide ceramic family, are well suited for this application due to their ability to withstand extremely high temperatures. Additionally, oxide ceramics alone are relatively inert in chemically active environments, while similarly jacketed thermocouples are still susceptible to the atmosphere and silica migration from the ceramic. An FCP circumvents oxidation/reduction attack and electrolytic degradation experienced by thermocouples.

Results from a research and development program support the premise that the FCP offers the potential to become a low-cost/high-reliability alternative for high-temperature applications where conventional techniques have proven unsatisfactory. Successful feasibility tests have been conducted in blast furnace cupolas (>1650°C), forging furnaces (>1425°C), Naval boiler flames (>1650°C), molten iron (>1540°C), and induction furnances (>2300°C).

Continuous measurements for over six hours in molten iron indicate that the FCP is a good candidate for control of various molten metal processes. In addition, several thousand hours have been amassed in forging furnaces to show that there is low calibration shift. In the forging furnace application, the advantages are responsiveness, the ability to directly operate pneumatic controllers (eliminating two electronic interfaces), and the elimination of the need for strategic materials such as platinum or chrome.

Furthermore, when one considers that a temperature standard is defined by the ability to calculate temperature precisely from first principles alone, then it is apparent why consideration is being given to the FCP for that purpose. With a precisely defined geometry and a well-defined fluid, the temperature can be readily and accurately calculated. Proposals for such a standard for temperatures above 1700°C have been made.

FOR ADDITIONAL INFORMATION: For further information on the FCP and other fluidic components and systems, contact: Harry Diamond Laboratories, ATTN: DELHD-RT-CD, Fluid Control Branch, 2800 Powder Mill Road, Adelphi, Maryland 20783; (202)394-3080. Refer to FC-103.

U.S. Army Fact Sheet

Fluidic Pressure Regulator

Pressure regulation is critical to fluidic circuits that are used for precision measurements or control. For example, the scale factors for signals from a bridge circuit are directly proportional to the bridge pressure. Also, the operation of the laminar jet angular rate sensor (LJARS) for low-threshold performance is highly dependent on maintaining a constant, quiet supply pressure. Mechanical pressure regulators have limited accuracy due to hysteresis and very low frequency response, both of which are undesirable for high-precision fluidic sensing. To overcome these problems, a fluidic pressure regulating circuit has been designed.

The fluidic regulator is based on a set-point sensor (figure 1) - modified laminar

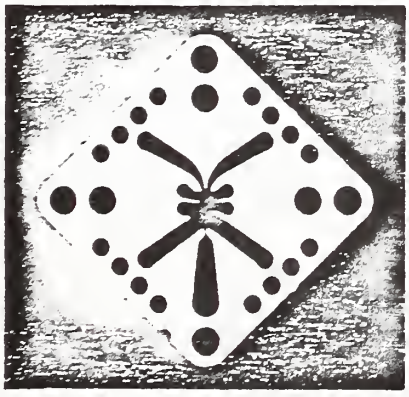


Figure 1. Set-point sensor.

proportional amplifier (LPA) in which the power nozzle has been aimed at one of the outputs, the control nozzles have been enlarged, and the control finger on one side has been set back significantly. With a variable resistor to ground attached to the "normal" control, the set-point sensor typically produces output-versus-supply pressure characteristics illustrated in figure 2. The curves have a gain of about 5-6 in the linear regions around the zero crossings.

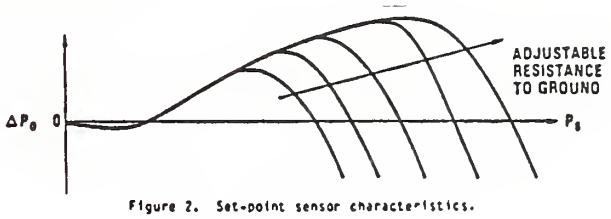


Figure 2. Set-point sensor characteristics.

Using these characteristics, the set-point sensor can be used with a three-stage LPA in a null-seeking circuit as shown in figure 3 to provide a regulated output pressure.

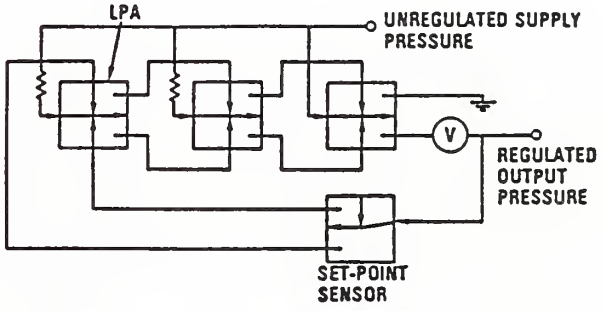


Figure 3. Schematic diagram of pressure regulating circuit.

The typical characteristics for such regulating circuits are presented in figure 4 where the family of curves represents different set-point conditions as established by the variable resistor to ground connected to the set-point sensor's control. Note that these curves exhibit a flat output range over a reasonably large change in applied supply pressure. Comparisons of this regulated pressure with equivalent values from a

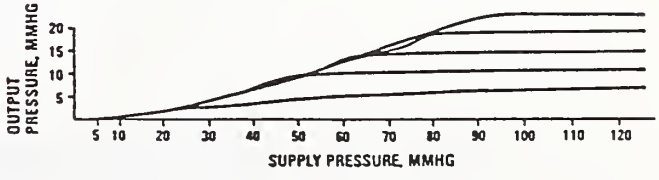


Figure 4. Typical performance characteristics of pressure regulating circuit.

high-quality mechanical regulator showed that the fluidic circuit was free of the saw-tooth signal generated by the mechanical regulator as it "hunts" for the nominal value. In addition, the fluidic regulator has a much higher frequency-response capability than do mechanical regulators.

This regulating circuit has excellent potential for use with a number of fluidic circuits. It may also find extensive applications in many ordinary (i.e. non-fluidic) sensing systems such as gas chromatography and medical devices where a high degree of regulation is essential to good performance.

FOR ADDITIONAL INFORMATION: For further information on the fluidic pressure regulator and other fluidic components and systems, contact: Harry Diamond Laboratories, ATTN: DELHD-RT-CD, Fluid Control Branch, 2800 Powder Mill Road, Adelphi, Maryland 20783; (202)394-3080. Refer to FC-112.

U.S. Army Fact Sheet

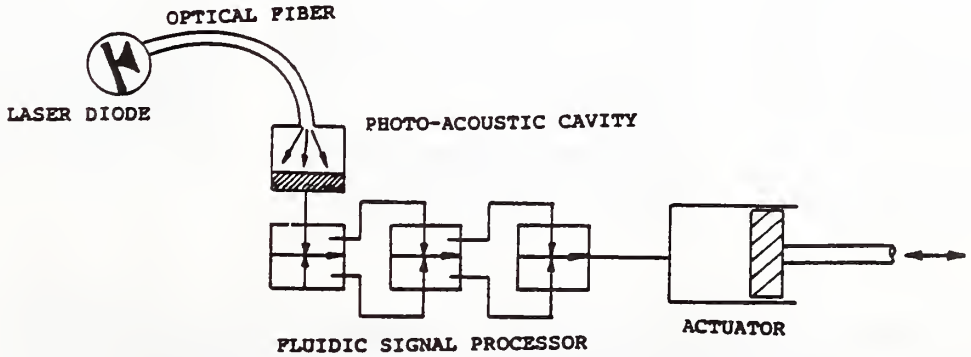
Opto-Fluidic Interface

A demonstration of a pneumatic photo-acoustic-fluidic convertor was made in 1980. Laser signals modulated at frequencies from 30 to 10,000 hertz were detected and processed by a fluidic frequency-to-analog convertor. The resulting analog output pressures of 10 to 30 psi, depending on the input signal (pulse-width modulated or frequency modulated), were used to drive a pair of pneumatic piston actuators that drove a mechanical linkage.

In 1985, a major breakthrough towards the realization of the goal of a hardened electro-hydraulic aircraft control system was achieved with the demonstration of a similar capability in hydraulic oil. Communication-power-level laser signals (0.25 - 2.5 milliwatts) were converted into hydraulic, acoustic signals and then amplified into hydraulic pressure signals of up to 0.01 psi at frequencies from 80 to 4,000 hertz. These signals, although small, are large enough to be fluidically processed to eventually drive a fluidic-input servovalve that may operate a hydraulic actuator.

The prognosis for "fly-by-light" flight control systems is now good. In such systems electro-optical signals will be transmitted to an actuator without interference from EMI or EMP, and mechanical motion will be developed without electro-mechanical conversion. That is, optical signals can be converted directly to fluid power. Thus a highly reliable, no-moving-parts, EMI-insensitive aircraft control system of the future may be realizable by utilizing technology.

Research continues to also develop an inverse conversion process, i.e. the direct conversion of fluid signals to electro-optical energy. When such devices become available, applications will include the real-time control of hazardous processes such as explosives manufacture, nuclear reactors, and dangerous materials production/handling. Under the control of a main computer/microprocessor, housed in some remotely-located, benign, environment, and connected to the process by two-way transmitting optical fibers, explosives could be processed without electric-spark hazards, nuclear reactors could be operated and controlled reliably without degradation in component performance, and dangerous (poisonous) materials could be processed by reliable, wear-free components that would never need a human to replace them.



OPTO-FLUIDIC INTERFACE

FOR ADDITIONAL INFORMATION: For more information call or write to: Harry Diamond Laboratories, ATTN: SLCHD-IT-R (Fluid Control Group) 2800 Powder Mill Rd., Adelphi, Md 20783; 202/394-3080. Refer to FC-107.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Spring-Blade Impact Tester

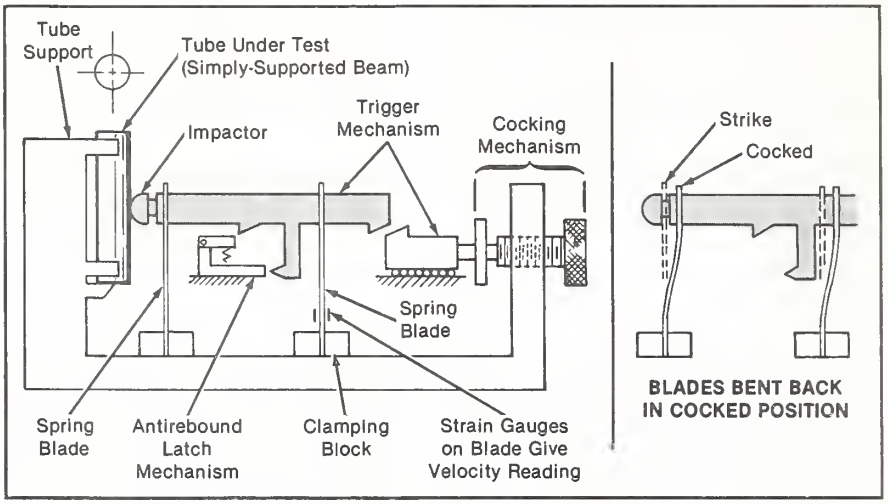
A record of energy relationships can be retrieved from a compact, portable tester.

The spring-blade impact tester was developed to support the evaluation of the tolerance to damage of struts under consideration for use in the Space Station. This approach offers the potential for determining damage as a function of the change in the relationship between applied and absorbed energies as the applied energy is successively increased with each impact. The concept also provides the potential for measuring behavior during impact, and the energy relationships are retrievable from oscilloscope traces of the impact.

The tester includes two identical flat spring blades set vertically and parallel to each other (see figure). The blades are clamped at the bottom to a massive plate that acts as a baseplate for the whole unit. At the upper ends, the blades are clamped to a single, rectangular-beam-like mass that spans the horizontal distance between them. When the mass is pulled horizontally in a direction that causes the blades to bend about their weak axis, the beam remains horizontal. Upon release of the pulling force, the mass travels back and forth horizontally with a decaying oscillatory motion.

Strain gauges installed on the blades measure the bending of the blades. A pair of back-to-back strain gauges mounted on each blade at a point other than at midheight, where strain is always zero, provides a signal proportional to the displacement of the blade at the moment of release.

The maximum kinetic energy of the oscillating mass is proportional to the volume of the two blades, the elastic modulus of the blade material, and the square of any measurable static elastic bending strain at the moment of release, if damping is assumed to be zero. Damping is not zero, but its highly repeatable effect can be measured, calibrated, and taken into account so that the maximum kinetic energy can be predictably set by monitoring and adjusting the static bending strain at the instant of release. The specimen is placed so that a special anvil attached to the mass strikes it at midoscillation, the moment of maximum kinetic energy.



The **Impactor Strikes the Specimen** at the moment of maximum kinetic energy after the spring blades are released from their cocked position.

Other features include a hydraulic actuator to pull the mass to its release position; a special releasing latch that provides a clean, sharp release actuated by the tap of an ordinary hammer; and a special latch that allows the mass to pass through the location of maximum kinetic energy only once. This second latch prevents repeated, oscillatory blows to the specimen. Because the energy available is a function of the volume of the spring-blade material, a minimum of space is required for operation and storage. The impact tester is compact and portable and is both easy and safe to use.

This work was done by Alan M. Holmes and James W. Champagne of Lockheed Missiles & Space Co., Inc., for **Langley Research Center**. *LAR-13749/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

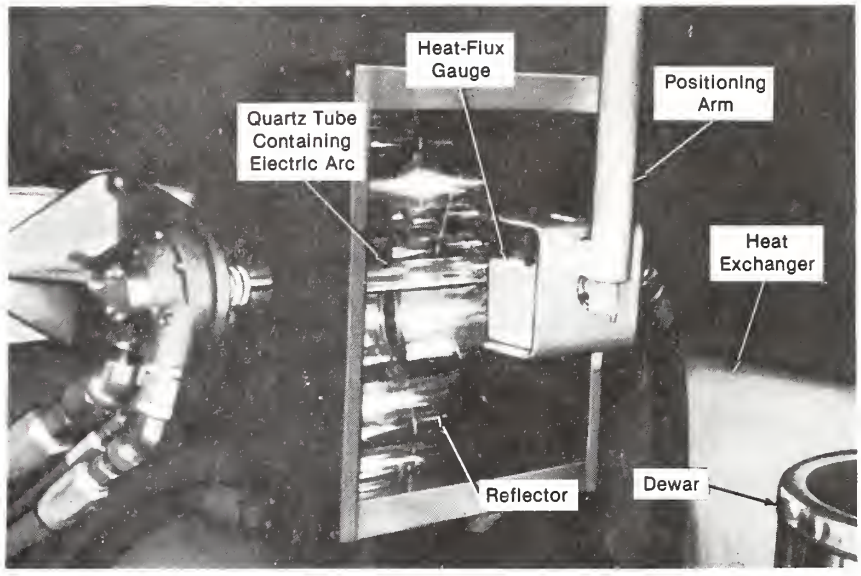
Automated Heat-Flux-Calibration Facility

Computer control speeds operation of the equipment and processing of measurements.

A new heat-flux-calibration facility has been developed at Lewis Research Center. This facility is used for fast-transient heat-transfer testing, durability testing, and calibration of heat-flux gauges. Calibrations can be performed at constant or transient heat fluxes ranging from 1 to 6 MW/m^2 and at temperatures ranging from 80 K to the melting temperatures of most materials. The facility was developed because there is a need to build and calibrate very-small heat-flux gauges for the Space Shuttle main engine (SSME). These heat-flux gauges are required for the measurement of the flux of heat to the surfaces of turbines in the turbopumps of the SSME.

The calibration facility includes a lamp head attached to the side of a service module, an argon-gas-recirculation module, a reflector, a heat exchanger, and a high-speed positioning system. The lamp head contains electric-arc-stabilization and deionized-water cooling systems. The stability of the arc, necessary for minimal fluctuation of the light (heat) source, is attained by giving the argon gas a high rotational velocity as the gas enters a quartz tube containing the arc, gas, and water (see figure).

The water is pumped in a spiral fashion along the tube and flows between the plasma arc and the quartz tube. Also, the deionized water cools the reflector, removes electrode debris from the inside surface of the tube, and cools the quartz tube. After the water has passed through the quartz tube, it is filtered within the service module and then cooled within the heat exchanger.



A 100-kW Arc Lamp provides repeatable, controllable directional radiant heating of the surface of a heat-flux gauge.

A positioning arm attached to the high-speed positioning system is used to position carefully the heat-flux gauge in the focus of the reflector; the positioning system also rapidly removes the gauge from the focal position after sufficient heating. Microcomputers built into the arc lamp and positioning system are controlled by a minicomputer stationed in a nearby control room. Before and after heating by the electric arc, the gauge is cooled by programming the minicomputer to position the gauge in a Dewar filled with liquid nitrogen.

Thermocouples attached to the bodies of heat-flux gauges produce voltages that are converted to temperature data and then stored in the minicomputer. The heat flux is calculated with computer codes that use measured gauge-body temperatures as input. This type of automated heat-flux-calibration facility can be installed in industrial plants for onsite calibration of heat-flux gauges that measure fluxes of heat in advanced gas-turbine and rocket engines.

This work was done by Curt H. Liebert and Donald H. Weikle of **Lewis Research Center**. *No further documentation is available.*

LEW-14724/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

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Environmental Science & Technology

1054 Power Plant Scrubbers Now Remove Nitrogen Oxides

Testing & Instrumentation

1055 Chemiluminescent Light Generating

1056 New Material can Help Gauge Sulfur Emissions

Other Items of Interest

1093 Review of Current Methods for Measuring Particulate Matter Including Condensables from Stationary Sources

Department of Energy

Technology Application

Lawrence Berkeley Laboratory

Power Plant Scrubbers Now Remove Nitrogen Oxides

Power plant emissions can be treated and transformed into commercial chemicals through new technology.

A research team has discovered a cost-effective process that allows power plant scrubbers, designed to remove sulfur dioxide, also to capture oxides of nitrogen. These compounds are the chemical precursors of acid rain and urban smog.

The system provides equal or improved treatment, removing 90 percent of sulfur dioxide and up to 100 percent of nitrogen oxides. Aside from performance, however, the technology has a corollary financial advantage. Preliminary economic analysis by the Bechtel Corp. indicates the process is one of the most economical high-quality treatment systems yet devised. Cost is the overriding factor affecting the success of emissions treatment technology.

Yellow phosphorus is fed into the scrubber along with the calcium-based slurry. Oxides of nitrogen consequently are removed along with the sulfur dioxide. Simple, effective, and inexpensive, the process may be the breakthrough that scientists worldwide have pursued for years.

Yellow phosphorus triggers a chain of chemical reactions within the scrubber that transforms insoluble gases into soluble compounds. The process reduces these soluble compounds into valuable industrial chemicals that can be sold. Unlike conventional desulfurization scrubber technology, the scrubber creates little or no waste sludge.

Most of the treatment byproducts consist of phosphoric acid and gypsum, but also ammonium phosphate. Phosphoric acid and ammonium phosphate can be used to manufacture fertilizers. Phosphoric acid also is used in metal treatment, catalysts, fuel cells, foods, and beverages. Gypsum is a construction material.

FOR ADDITIONAL INFORMATION: Public Information Department, Lawrence Berkeley Laboratory, Cyclotron Road, Berkeley, California 94720; (415)486-5771.

Ames Laboratory

Chemiluminescent Light Generating

Hydrogen sulfide is often emitted into the atmosphere during the industrial production of methanol, methane, glycols and other hydrocarbons. The toxicity of this gas makes it critically important to be able to continuously monitor its presence in the atmosphere. Amounts as small as one part per million can also poison costly catalysts used to produce petrochemicals. Continuous monitoring by present methods is difficult and requires long collection times, concentration of the hydrogen sulfide and time-consuming chemical preparation. Thus, truly continuous monitoring cannot be achieved.

Ames Laboratory researchers have addressed this problem by developing a way to continuously monitor hydrogen sulfide and methyl mercaptan (another sulfur-containing compound) at levels as low as one part per billion, and with high sensitivity. The method is based on a new reaction that involves chemiluminescent technology for detection. Chemiluminescence refers to the ability of materials to give off a faint glow during reactions with certain chemical compounds. The Ames researchers have discovered that hydrogen sulfide or methyl mercaptan will react with chlorine dioxide and produce sulfur atoms. These sulfur atoms recombine to form electronically excited S2 which luminesces. A single photon is emitted for every two sulfide-containing species, thus providing a qualitative and quantitative measurement of the toxic compounds. The volume of the reaction zone must be small and ClO_2 gas must be kept in excess. This method improves upon existing technology in that it is absent of interfering signals from other components in the atmosphere, eliminates errors, and permits truly continuous monitoring. For more information on the Technology contact Daniel E. Williams (515) 294-2635.

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

New Material can Help Gauge Sulfur Emissions

Two new standard reference materials (SRMs), developed to help ensure that laboratories make accurate analyses of sulfur emissions produced by U.S. pulp and paper industries, are now available from NIST. The SRMs are intended for calibrating laboratory instruments and for evaluating the methods used for determining the concentration of hydrogen sulfide emitted into the atmosphere. Supplied in aluminum cylinders, the SRMs represent two concentrations of hydrogen sulfide: 5 and 20 parts per million. The materials cost $730 per cylinder and may be ordered from the Office of Standard Reference Materials, NIST, B311 Chemistry Building, Gaithersburg, Md. 20899; telephone: 301/975-6776. The new materials are among the more than 1,000 different SRMs available in NIST's inventory. Each year about 44,000 units are sold to over 10,000 customers throughout the world. Funds from SRM sales cover the cost of production, certification, and distribution of the materials.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

Manufacturing, Machinery & Tools

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1059 Inversion of Jacobian Matrix for Robot Manipulators—A closed-form transformation from task space to joint space is computed efficiently.

1060 Making Multicore, Multishell Microspheres—Multiple streams of fluids would be combined to produce various structures. (Licensing Opportunity)

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Other Items of Interest

1018 Process for Patterning Dispenser-Cathode Surfaces—Microfabrication techniques increase uniformity.

1025 Achromatical Optical Correlator—The signal-to-noise ratio should exceed that of a monochromatic correlator.

1036 Advanced Engraving of Angle-Encoder Disks—Precision would be increased over that of mechanical engravers. (Licensing Opportunity)

Linear Coal Cutting Concept Reduces Respirable Dust Generation and Provides Larger, More Uniform Product

Design a high-production coal mining machine with inherent low dust generation and low frictional ignition potential.

Constant depth linear cutting (CDLC) provides a long-term solution to excessive dust generation from shearers and continuous mining machines through new design of the rotary drum cutting system. Problems with rotary drum systems, which must be eliminated to control the dust generation at the source, include the effect of a constantly varying depth of cut using fixed bit spacing, secondary fragmentation of already broken coal, and frictional heating of bits and entrainment of dust by fanning action due to high drum rotational speed. Each bit on a rotary drum enters the coal face at zero depth of cut, goes to some maximum depth at the horizontal centerline during sump, and exists at zero depth.

When the bits are cutting between 0 and 70 pct of maximum depth, they recover approximately 10 pct of the total product from the cut but they produce approximately 75 pct of the total dust and use approximately 75 pct of the total energy. The bits are effectively fragmenting coal only when they are between 70 pct depth and their maximum depth of cut, where they recover the other 90 pct of the total volume. It follows that to design an optimum cutting system, the low-recovery portion at a shallow depth of cut with the rotary drum must be designed out of the system to minimize dust.

In addition to the shallow cutting portion of a rotary drum, there is an inherent secondary dust generation source in this design, due to regrinding of already fragmented coal, that may be 100 to 1,000 times greater than any primary dust generation. This suggests the optimum way to reduce dust generation and entrainment is to eliminate regrinding by cutting to a free face at low drum rotational speed.

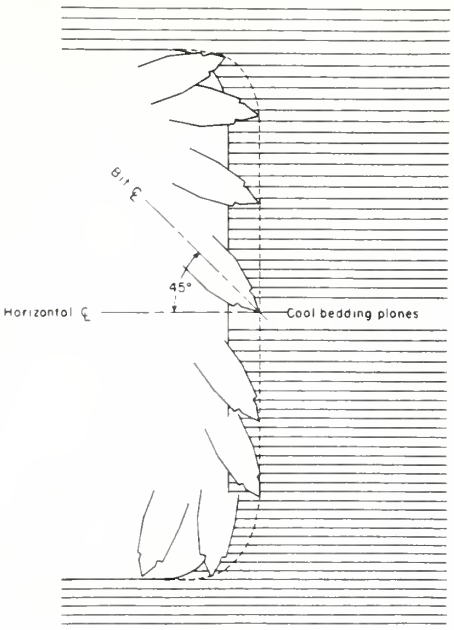
The CDLC concept is designed to cut to a free face by using an eccentrically mounted triangular shaped drum. In addition to breaking to a free face with no secondary fragmentation, the CDLC will have a bit velocity well below the minimum needed for phase shifts in the bit metals or for methane ignition. This will reduce the bit wear rate and reduce, if not eliminate, methane ignition due to cutting.

A comparison of the cutting forces, respirable dust generation, and screened product size between the CDLC concept and a rotary cutting drum is shown in the following tabulation. Laboratory tests were

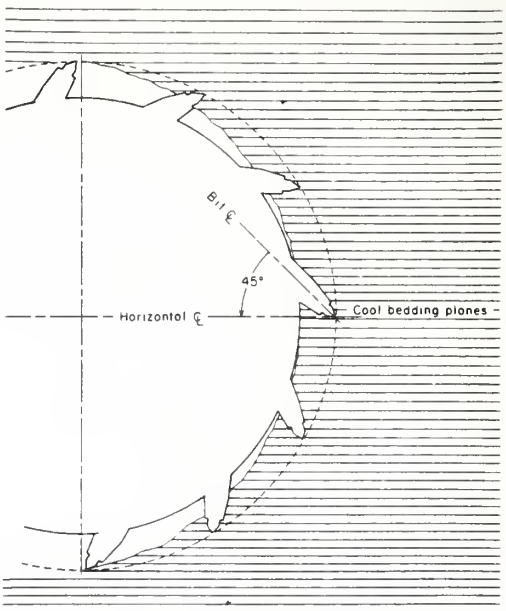
The Bureau's CDLC proof-of-concept test stand after a test.

Comparison of CDLC and Rotary Cutting

Parameter	CDLC	Rotary
Rotational speed . . . rpm . .	10	50
Max depth cut per bit . . in . .	1	1
Max peak forces . . . . . kN . .	8	10
Respirable dust . . . . . mg . .	1	34
Product <1/4th mesh . pct . .	12	25



CDLC path.



Rotary drum cutting path.

conducted in coalcrete, a synthetic coal material requiring the same cutting forces as coal. The rotary cutting cylindrical drum was operated at speeds typical of present mining practices.

It can be seen from this tabulation that the respirable dust is reduced by more than 95 pct, median product size has increased, reducing fines by more than 50 pct, and the cutting forces are down by 20 pct. At 10 rpm there will be no problems due to frictional heating of the bits.

The CDLC concept will significantly reduce respirable dust and fines generation and reduce, if not eliminate, methane ignitions due to frictional heating. The CDLC system will cut substantially greater amounts of coal while keeping the amount of dust generated within the regulatory limit. The system will provide a product with fewer fines and thus reduce losses at the preparation plant, which will improve production and increase the economic return for the operator.

Four patents have been granted relevant to this development: 4,025,116, 4,012,077, 4,062,595, and 4,303,277. For information about these patents or on patent licenses, please contact the Office of Technology Transfer, U.S. bureau of Mines, MS 6201, 2401 E St., NW., Washington, DC 20241-0001.

FOR ADDITIONAL INFORMATION: Requests for additional technical information about the CDLC concept should be addressed to the principal investigator: Wallace W. Reopke, Twin Cities Research Center, U.S. Bureau of Mines, 5629 Minnehaha Avenue South, Minneapolis, MN 55417-3099, (612-725-4780).

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

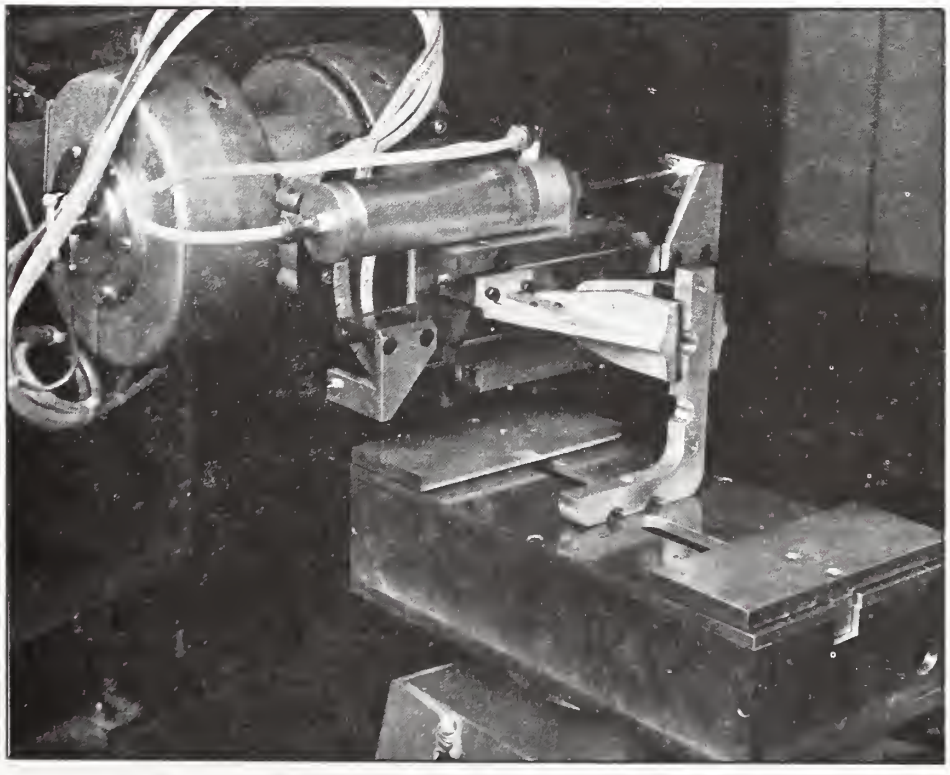
Off-Line Programming System Improves Safety and Economy

The Off-Line Programming (OLP) System developed at the AMRF's Cleaning and Deburring Workstation (CDWS) improves the workstation's safety and economy while increasing its flexibility.

Off-line programming allows the user to develop and test robot and machine-tool programs without actually operating the equipment.

AMRF researchers combined simulation, integration techniques, and sensory interaction in the design of the system. Workstation safety is improved through the use of simulation to check for robot programming errors before actual operation of the equipment. Its economy is improved by eliminating the teach-pendant method of robot programming which minimizes downtime.

An effective OLP system must interface between commercial components by communicating with a CAD system at the input-side of the OLP process and with the robot controller at the output-side. The CDWS's OLP implementation transfers a wireframe model of the part from the CAD system to the OLP system (via IGES). All workstation components and robot trajectories are then modeled in the commercial OLP system. A simulation program which operates and synchronizes all workstation devices is produced and downloaded to the workstation for execution.



The use of off-line programming assures that this part is properly placed for deburring.

wheel. This force sampler measures the forces incurred at different locations on the buffing wheel during buffing. This information provides a location-force model of the buffing wheel for use in simulation.

To assure that a program generated off-line is robust, the programmer must have maximum information about the real world. Research at the Cleaning and Deburring Workstation has helped confirm that the requirements for a complete world model which operates in a dynamic environment must include not only an accurate geometric model but simulation of sensory-based robot programming as well. Off-line sensory-based robot programming involves both a sensor-based robot programming language and a means of simulating general classes of sensors such as force-torque, tactile, proximity, and vision.

The first working implementation of the OLP system was demonstrated at the 1988 Open House of the AMRF Automation Program. Visitors to this year's Open House will see a demonstration of an enhanced version of the system.

The model of the environment must be accurate for the simulated program to be reliable. The workspace must be calibrated to accurately record all workspace devices in the model. To do this, AMRF researchers developed a calibration gripper equipped with ultrasound sensors which find the actual location of objects in the workspace relative to the robot. This information is used to correct the simulated model of the environment. Calibration also improves robot performance by compensating for inaccuracies in the robot and assuring that trajectories developed in simulation will be safe in the real world.

To complete the model, other qualities such as the stiffness of the objects associated with a task must be known. To get this information, CDWS researchers developed a force sampling end-effector which provides force feedback of, in this case, the workstation's buffing

FOR ADDITIONAL INFORMATION:
To discuss these efforts further, contact
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NASA Tech Brief
National Aeronautics and
Space Administration

Inversion of Jacobian Matrix for Robot Manipulators

A closed-form transformation from task space to joint space is computed efficiently.

A report discusses the inversion of the Jacobian matrix for a class of six-degree-of-freedom arms with spherical wrist, i.e., with the last three joints intersecting. The authors show that by taking advantage of the simple geometry of such arms, the closed-form solution of $\mathbf{Q} = J^{-1}\mathbf{X}$, which represents a linear transformation from task space to joint space, can be obtained efficiently.

The inverse transformation, represented as $\mathbf{Q} = J^{-1}\mathbf{X}$, is essential for the implementation of the advanced task-space control schemes since the actuation; i.e., the application of forces/torques is ultimately performed at the joints level. However, while the forward transformation, given as $\mathbf{Q} = J\mathbf{X}$, presents no major problem, the computation of the inverse transformation is more difficult, and previous authors have studied ways to perform it efficiently. The main motivation in the development of the previous methods has been to avoid the prohibitive computational cost, which arises from the symbolic or numerical computation of the Jacobian and its numerical inversion.

The theoretical development in this paper involves the derivation of the Jacobian vectorial matrix, which is a general form of the Jacobian from which specific Jacobians can be derived by a set of appropriate transformation, i.e., velocity reference point transformation as well as projection onto the applicable coordinates. The authors develop a relatively simple method in which the Jacobian vectorial matrix and corresponding transformations are derived by relating the velocity of two points. It is shown that any specific Jacobian can be described in terms of another Jacobian with arbitrary choice of velocity reference point and coordinate frame, which can be chosen to yield the Jacobian in its simplest symbolical form leading to its symbolic inversion and the closed-form solution of $\mathbf{Q} = J^{-1}\mathbf{X}$.

The report presents solutions for a PUMA arm, a JPL/Stanford arm, and a six-revolute-joint coplanar arm along with all singular points. The solution for each joint variable is found as an explicit function of the singular points, thus providing better insight into the effect of the singular points on the motion of, and force/torque exerted by, each joint.

The main contribution of this paper is to show that the simple geometry of this type of arms can be exploited in performing the inverse transformation without any need to compute the Jacobian or its inverse explicitly. The cost of computing the inverse transformation becomes of the same order as that of the cost of computing forward kinematic position transformation, and it is significantly reduced if this transformation is already performed. The implication of this computational efficiency is that advanced task-space control schemes for spherical-wrist arms can be implemented more efficiently.

This work was done by Amir Fijany and Antal K. Bejczy of Caltech for **NASA's Jet Propulsion Laboratory.** *"Efficient Jacobian Inversion for the Control of Simple Robot Manipulators."*
NPO-17544/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Making Multicore, Multishell Microspheres

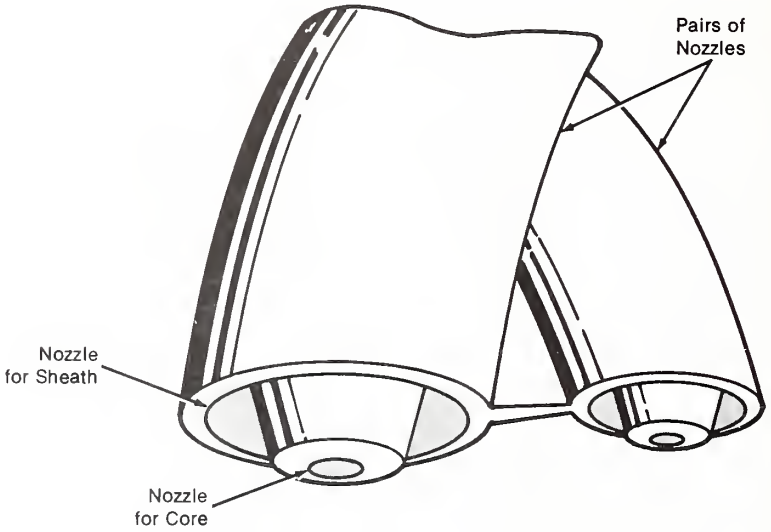
Multiple streams of fluids would be combined to produce various structures.

Spherical or nearly spherical microshells containing two or more discrete inclusions, like eggs with more than one yolk, would be produced by a proposed technique. For example, a glass shell might hold a bubble of hydrogen adjacent to one of oxygen.

If desired, the spheres could be designed so that the cores combine to mix or react only after leaving the shell generator. Similarly, two or more shell-wall materials could mix or react after leaving the generator.

The technique would involve two (or more) pairs of coaxial nozzles (see figure). The converging jets of fluids from the separate nozzles would combine by surface tension, forming a liquid bridge of dog-bone-shaped cross section. The stream would eventually contract into a round cross section and break up into droplets. The apparatus could deliver one, two, or more different outer-shell-material streams with one, two, or more different core materials, each entrained in its own outer stream.

The droplet shells would solidify by freezing or by chemical reaction. The shell would be more or less spherical, but the precise shapes would depend on centering forces, surface tensions, temperatures, and aerodynamic and gravitational forces acting on the falling droplets. The extent of mixing or reaction of the shell and filler materials would depend on such properties of the materials as the viscosity and surface tension and on such controllable system parameters as the temperature, velocities, and volumes of the droplets.



Pairs of Coaxial Nozzles would be combined in arrays of two or more. Each pair of nozzles would generate an inner jet surrounded by a sheath of fluid. The multiple jets would combine to form droplets composed of shells and cores.

This work was done by Andrew D. Morrison of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL
Refer to NPO-17203/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Structurally-Tailorable, Nonlinear, Snap-Through Spring

An abrupt change in load/deflection response is controllable and predictable.

A structurally-tailorable, nonlinear, snap-through spring (STNSTS) exhibits a controllable and predictable abrupt change in load/deflection response and is based upon a known phenomenon of snap-through structural response. The STNSTS is composed of a pin-connected two-bar linkage as shown in Figure 1, which depicts combined tension/compression springs. As load is applied to the STNSTS, the stiffness is a function of the internal spring and the bending stiffness of the pin-connected bars. As the load increases, the bars deform laterally until they collapse and snap through (Figure 2).

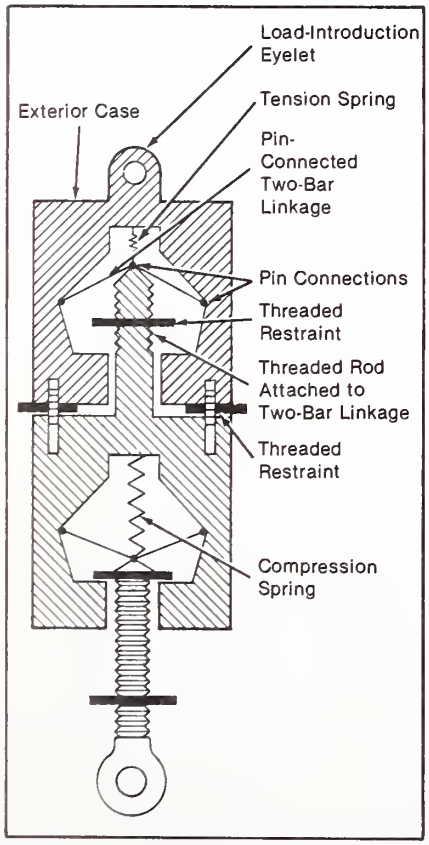

Figure 1. The **STNSTS Can Be Structurally Tailored** in both tension and compression configurations.

When the snap through occurs, a large deformation occurs as a result of a small increment of the applied load. After the snap through, the load/deflection response becomes a function of stiffness of the internal spring and the membrane stiffness of the bars. Additional stiffness can be provided by restraints in contact with the spring case. The restraints limit the deflection of the internal spring/two-bar linkage. Once the restraints make contact with the spring case, the load/deflection response of the STNSTS is a function of the stiffness of the internal spring, the membrane stiffness of the bars, and the stiffness of the spring case.

The load/deflection response of the STNSTS is tailorable by changing the size, stiffness, and orientation of its components. Multiple devices can be placed in parallel or series to produce an infinite number of different load/deflection responses. The STNSTS has potential application in passively-tailored rotor-blade flap, pitch, and lag response, to improve the aerodynamic performance and stability characteristics of rotors; in aerodynamically- and aeroelastically-tailored wing spars and ribs, to produce a tailored deformation state for improved effectiveness in maneuvering, aerodynamic performance, and stability characteristics; and in energy absorbers for automobile bumpers and aircraft landing gear.

This work was done by James H. Starnes, Jr., of **Langley Research Center** *and Gary L. Farley and Wayne R. Mantay of the U.S. Army Aerostructures Directorate. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13729/TN.

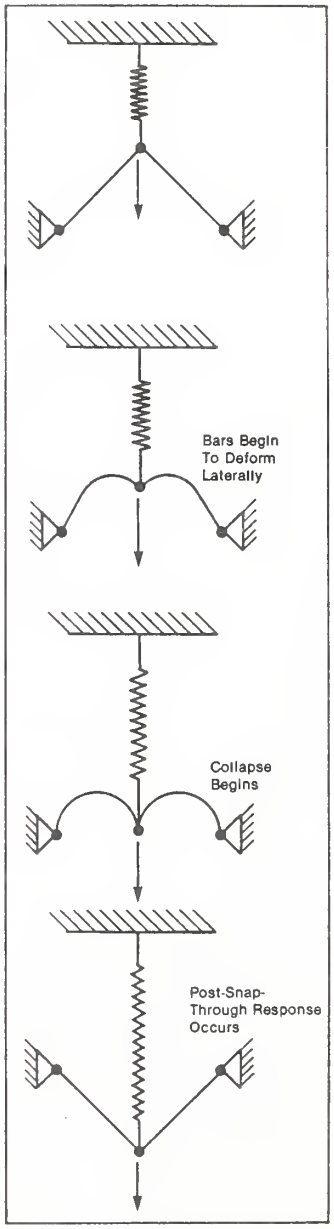

Figure 2. **Bars Deform and Collapse** to produce snap-through spring response.

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Materials

1062 Electrophoretic Coating Process Finding New Applications

1063 Building Quality into Advanced Materials During Processing

1064 Ductile-to-Brittle Fracture Behavior of Steel

1065 High-Quality Amorphous Silicon Films Produced

1066 Ignition of Steel in Oxygen Atmospheres

1067 Process Developed to Remove Twins in YCBO Crystals

1068 Carbon/Carbon Panels Cooled by Heat Pipes—Heat pipes are embedded to suppress hotspots. (Licensing Opportunity)

1069 Chemical-Vapor Deposition of Cd1-xMn$_x$Te—An experimental process makes films with interesting magnetic and magneto-optical properties. (Licensing Opportunity)

1070 Effect of Solidification Speed on Fatigue Properties—Fast solidification increases fatigue life, but the failure distribution becomes less predictable. (Licensing Opportunity)

1071 Isothermal Equation of State for Compressed Solids—The same equation with three adjustable parameters applies to different materials.

1072 Measuring Crack Growth Rates in Ti-6A1-4V

1073 Microencapsulated Phase-Change Materials for Storage of Heat—Investigations concentrate on the feasibility of practical, safe, lightweight systems.

Testing & Instrumentation

1076 Thermal Analysis of Reluctant Glass Formers—A thermocouple holds a sample and monitors its temperature during cooling.

1077 Quality Evaluation by Acousto-Ultrasonic Testing of Composites—This promising nondestructive-testing method is based on ultrasonic simulation of stress waves.

Other Items of Interest

1032 Equation Developed for Predicting Steels in Fire

1044 Fluidized-Bed Reactor with Zone Heating—Deposition of silicon on the wall is suppressed.

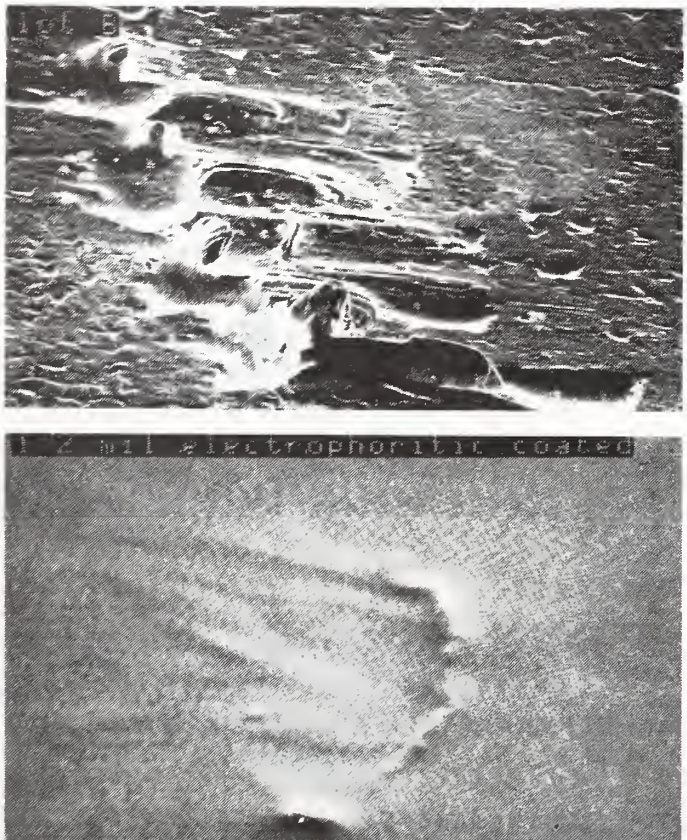
1060 Making Multicore, Multishell Microspheres—Multiple streams of fluids would be combined to produce various structures. (Licensing Opportunity)

Sandia National Laboratory

Electrophoretic Coating Process Finding New Applications

A process first developed in the 19th century is helping researchers at Sandia National Laboratories make high-technology, high-voltage switches for use in particle beam research.

The coating technology for electrophoretically applying very thin coatings to materials appears to have applications in the manufacture of high-performance electrical motors and more efficient transformers. It is also being applied in solar photovoltaic work at Sandia and is being studied for applications in medicine, weapons, communications, and other fields.



Metglas foil before (top photo) and after electrophoretic coating with protective styrene-acrylate.

Electrophoresis was developed in the last century in Germany and is now widely used as a chemical and biological analytic tool. It is a process where charged particles migrate in solution under the influence of an electrical current to coat metal surfaces. A major advantage of electrophoresis coating compared with conventional electrolysis is that it permits the plating of thin films of nonmetallic materials. Using the electrophoretic (EP) technique to apply thin, even coatings has proven to be cost-effective in a number of applications, according to Donald J. Sharp, of Sandia's Interfacial Chemistry and Coatings Research Division.

In the case of the switching devices now being studied for production, an amorphous metal foil, called Metglas, is wound to form inductors, or coils, using a thin Mylar plastic insulating film. The switches are being designed to provide trillions of watts of power for tens of nanoseconds in future particle beam accelerators. The Metglas foil was deemed desirable because its lack of crystalline structure results in lower losses than can be achieved with other high-saturation, flux-density magnetic materials. During operation, voltages approaching 1000 volts may appear between each of the many turns of this material.

Metglas foil must be tightly wound to achieve this magnetic density, which rules out thick insulation between foil layers.

Metal microspikes on the foil present problems. The spikes penetrate or damage the 12-micrometer-thick Mylar film, used as insulation. This results in electrical shorts across foil layers before system saturation - sometimes even before high

voltages were applied to the system.

Thomas G. McDonald and Sharp found they could apply thin, uniform EP coatings on the microspikes. "It was like buttering them. After the coating only a few peaks stuck out of the coating," says Sharp. The coatings prevent the microspikes from tearing the insulating Mylar. The resulting inductors demonstrated breakdown voltages of about 6000 volts - a 240 percent improvement compared to the uncoated foil.

To perfect the EP coating procedure, McDonald conducted laboratory tests with a styrene-acrylate commercial polymer mix. Next a continuous processing machine was constructed for coating 2-inch-wide strips of foil several hundred feet long. H. C. (Chuck) Harjes and G. A. Mann of Sandia's Pulsed Power Research and Engineering Division helped in the design of the research machine, making use of information developed by McDonald and Sharp.

Placed in an air-filtered enclosure, the device carries the foil through an EP bath, a drying station and a polymer curing (or heat-treating) column. In the bath, a current is passed through a mixture of deionized water and the styrene acrylate resin. (In other applications, powdered glass or other coating materials can be mixed with water.) The acrylate molecules in solution take on a negative charge. Depending on the current and the length of time it is applied, EP coatings of varying thicknesses are deposited on the foil, which acts as an anode, or positively charged electrode, in the system. When an electrical current is applied, the macromolecules of suspended polymer begin to migrate, clump together, and attach themselves to the foil.

Results to date indicate that coating thicknesses of up to 25 micrometers - slightly smaller than the diameter of a fine human hair - are possible with appropriate currents and baking temperatures for the polymers. The EP coating procedure has also worked very well on irregularly shaped objects, Sharp reports. Corner areas, which typically aren't well coated in spray processes, tend to be well coated in electrophoresis because the electrical charges are strong in these areas.

Plans have been made, pending funding, to design a larger process machine for coating the lengths of Metglas foil required to make the large switching inductors. Several miles of the two-inch-wide material will be needed for this purpose.

Private industry is watching closely, says Sharp, largely because of potential uses for the spiky Metglas foils. Among these are more efficient electric motors (one was recently used in a solar-powered racing car) and for use in improving efficiency in transformers. Metglas transformers with the acrylate coating could reduce power transmission losses through better efficiency, an attractive idea for utility companies.

EP depositions require an initial investment for processing tanks, a power supply, and an oven for drying, sintering, or heat-treating coatings. The process requires minimal operator skills once set up, Sharp notes.

Tests of a number of applications result in several general cautions from Sharp and his colleagues about EP coatings. They include: Coatings may be soft and poorly adherent on surfaces until they have been cured or sintered. Curing promotes cross linking, drives off liquids, and improves the coating's sticking power; If there is a large mismatch between the thermal expansion of the coating and material being coated, cracking or peeling may occur; Deposition surfaces must be electrically conductive.

Despite these limitations, Sandia research has shown a number of cases where the EP coating process is of value. In addition to the styrene, a number of powders have been deposited. These include: glasses, mica, silicon and titanium dioxide, aluminum and zirconium oxide and titanium diboride.

FOR ADDITIONAL INFORMATION: Public Information Division, Code 3161, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800; (505)844-4207. Refer to announcement 24, No. 6.

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Building Quality into Advanced Materials During Processing

Materials scientists at the National Institute of Standards and Technology are seeking researchers in industry, universities, and other organizations who are interested in participating in collaborative programs on the intelligent processing of materials (IPM). The IPM concept is a new computer-based approach for producing advanced polymer, ceramic, and metal alloy materials that are far superior to those used today. The special properties of advanced materials are the results of microstructures designed and built into them during processing. An IPM facility with various on-line nondestructive evaluation (NDE) sensors and process models can monitor and control carefully the processing conditions required to give advanced materials many exceptional qualities, such as improved strength, unusual magnetic properties, and increased resistance to heat, friction, wear, and corrosion.

Tom Yolken, chief of the NIST Office of Nondestructive Evaluation, points out that the annual world market for advanced materials and for the products made from them is estimated to reach $300 billion by the year 2000. There also is a sizeable market for conventional materials that are improved by the use of intelligent processing technology.

Lyle H. Schwartz, director of the NIST Institute for Materials Science and Engineering, says, "Our long-range goal is to develop the scientific and measurement base that is crucial to U.S. industry's success in capturing a significant share of the world market for advanced materials."

According to Yolken, advanced materials tend to be expensive because their production is labor intensive and rejection rates are high. The unpredictable variability of properties also prevents designers from exploiting the technological advantages of advanced materials. He points out that the intelligent processing of materials concept will allow for quality to be built into materials during processing rather than attempting to obtain it by inspection.

Intelligent processing technology involves four principal interconnected parts:

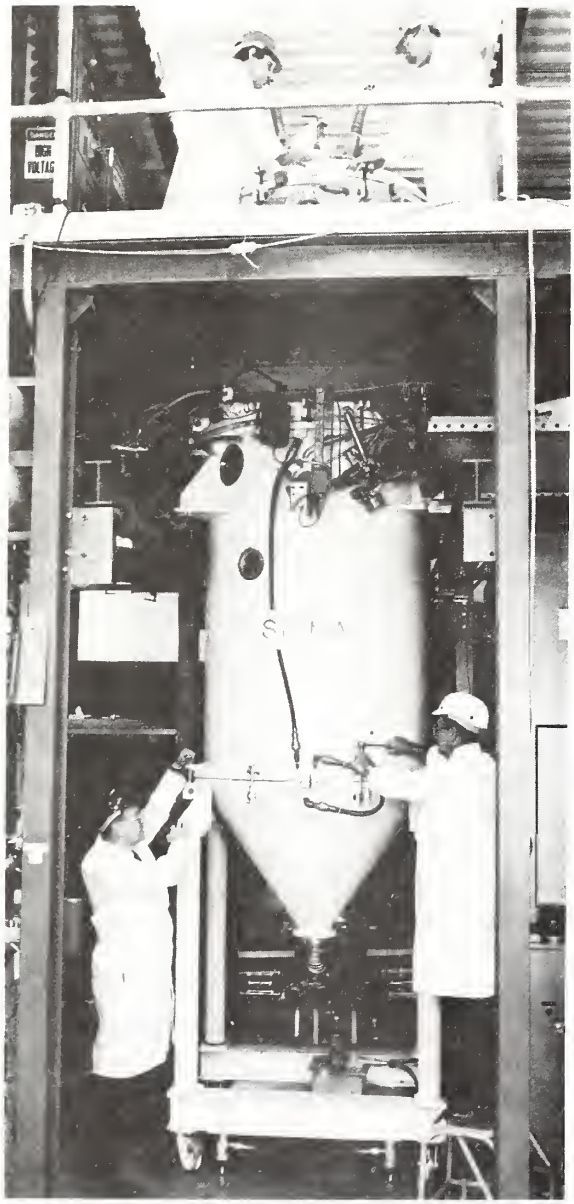
- the materials processor—various apparatuses to press, cast, or mold materials;
- a network of on-line NDE sensors to measure or monitor the microstructures of materials during processing;
- control devices, such as valves, pumps, and motors, that regulate pressure, temperature, and other processing requirements; and
- a computerized process controller that closes the loop between the sensors and the process controls.

The process controller incorporates various expert systems, process models, and data. This computerized "decision-maker" can quickly evaluate information and make rapid adjustments in production processes to achieve the desired microstructures in advanced materials.

Yolken emphasizes that IPM technology differs greatly from conventional automated processing where variables, such as temperature and pressure, are automatically controlled to preselected values. This does not allow for variations in the incoming materials. The IPM concept uses on-line measurements in real time to control simultaneously a wide variety of processing parameters.

Now there are two IPM pilot demonstrations under development at NIST. An industrial consortium has been established to automate the production of rapidly solidified metal powders by high-pressure gas atomization. The total IPM package will consist of sensors, process mod-

els, and an "expert" computer system to control the atomization of liquid metals to produce powders with the desired microstructures for advanced metal alloys.



Researchers at NIST prepare for a test run using the supersonic inert gas metal atomizer (SIGMA). Clockwise from bottom left are John Manning, Frank Biancaniello, Stephen Ridder, and James Ingram, a research associate from Hoeganaes Corporation.

In another IPM project, NIST scientists are working with researchers from government, industry, and universities in a collaborative program on the hot isostatic pressing (HIPing) of titanium aluminide. The researchers are developing sensors, process models, and other measurement tools to automate the entire production cycle, from raw metal powders to finished parts at near-net, or close-to-final, shapes.

In addition to the pilot demonstrations, NIST long-range plans call for collaborative IPM programs in polymers processing, ceramics processing, and the thermomechanical processing of metals. These programs will address industry needs that were identified by specialists at a national workshop on the intelligent processing of materials.

Collaborative IPM research opportunities are available where guest scientists from industry, government, and universities are able to work at NIST on projects of mutual interest with salaries paid by their employers. For information, contact the Office of Nondestructive Evaluation, NIST, B344 Materials Bldg., Gaithersburg, MD 20899, 301/975-5727. The NDE office also may be contacted for a copy of *Intelligent Processing of Materials, Report of an Industrial Workshop Conducted by the National Institute of Standards and Technology* (NISTIR 89-4024).

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Ductile-to-Brittle Fracture Behavior of Steel

Although the fracture behavior of steels is understood at high and at very low temperatures, the behavior at intermediate temperatures has been hard to characterize. In this ductile-to-brittle transition region, measurements of the fracture toughness as a function of temperature show a large scatter, and measurements of different-sized specimens at different loading rates give different results. A NIST guest scientist from West Germany has clarified the cause of this variability on a quenched and tempered pressure vessel steel (DIN 20 MnMoNi 55, similar to ASTM A533B). Four different types of fracture initiation sites have been identified, including cleavage facets, inclusions, clusters of inclusions, and local zones of ductile tearing. The fracture toughness depends on the distance from the crack tip to the initiation site.

FOR ADDITIONAL INFORMATION: The study results are published in Fracture Behavior of a Pressure Vessel Steel in the Ductile-to-Brittle Transition Region (NISTIR 88-3099), available from the National Technical Information Service, Springfield, Va. 22161; (703)487-4600.

NTIS order number: PB89-189195NAC
Price code: A03

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

High-Quality Amorphous Silicon Films Produced

Government, industry, and academia are working to develop an inexpensive source of solar electricity - amorphous silicon photovoltaic solar cells. NIST and University of Colorado researchers at the Joint Institute for Laboratory Astrophysics have produced high-quality hydrogenated amorphous silicon films by decomposing silane gas on a very hot surface and depositing it on a nearby relatively cool 210 degrees Celsius substrate. The technique uses a low-pressure feed gas that offers great potential for high deposition rates, above 1 nm per second. The results obtained in this work demonstrate a low incidence of defects, which interfere with the photovoltaic efficiency and electron transport mechanisms. While high deposition rates were not the goal of the research, a low-pressure feed gas can be efficiently dissociated into a large flux of depositing radicals so that the technique looks promising for more efficient production of solar cells. The low pressure also avoids the undesirable production of dust which introduces defects into the deposited layers.

FOR ADDITIONAL INFORMATION: A paper describing the process is available from Jo Emery, NIST, Division 104, Boulder, Colo. 80303; (303)497-3237.

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Ignition of Steel in Oxygen Atmospheres

Many high-strength alloys burn readily in pressurized oxygen atmospheres, a fact of interest to many in science and engineering, but of particular consequence to the aerospace community. For several years, NIST has conducted studies sponsored by NASA of the ignition and combustion of various iron-, aluminum-, nickel-, and cobalt-based alloys in oxygen. The purpose of the work is to gain a fundamental understanding of the ignition characteristics of broad classes of metals in oxygen atmospheres. The results of the latest tests on a stainless steel alloy (UNS S66286) are now available.

FOR ADDITIONAL INFORMATION: The details of the tests are presented in Ignition Characteristics of the Iron-Based Alloy UNS S66286 in Pressurized Oxygen (NISTIR 88-3904), available from the National Technical Information Service, Springfield, Va. 22161; (703)487-4600.

NTIS order number: PB89-1893R36NAC
Price code: A03

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Process Developed to Remove Twins in YCBO Crystals

A new technique for removing the twins in yttrium-barium-copper-oxygen (YBCO) single crystals may help scientists to understand better the performance of high-temperature superconducting materials. Twins are the interchange of the crystallographic a and b axes of a single crystal that occurs during processing as the material cools. These defects may contribute to superconductivity, but they also are barriers to information on the structure and properties of materials. The detwinning process uses pressure and heat to align the a axis parallel to the direction of applied stress. By characterizing untwinned single crystals, scientists will be able to determine the a/b strucural and property anisotropy or directionality, and the effects of twin boundaries on superconductivity. Polarized light, optical microscopy, and x-ray studies were used to verify the new technique.

FOR ADDITIONAL INFORMATION: For a copy of a report on the NIST detwinning process, send a self-addressed mailing label to Dr. Frank W. Gayle, NIST, A153 Materials Bldg., Gaithersburg, Md. 20899.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Carbon/Carbon Panels Cooled by Heat Pipes

Heat pipes are embedded to suppress hotspots.

A durable and reusable high-temperature carbon/carbon heat-pipe structure operates at temperatures above 3,000 °F (1,649 °C) in a vacuum or inert environment and up to 2,800 °F (1,537 °C) in an oxidizing environment. The maximum heat-flux capability of a carbon/carbon structure is currently limited by the temperature capability (about 2,800 °F) of its oxidation protection system. The new concept combines high-temperature heat-pipe and carbon/carbon technologies to extend both the thermal structural capabilities of refractory-metal heat pipes and the maximum heat-flux capability of carbon/carbon structures.

This new design uses refractory-metal heat pipes embedded within a carbon/carbon structure (see figure). The walls of the heat pipes are thin and contain the working fluid (lithium or sodium) of the heat pipe. The carbon/carbon acts as the primary load-carrying part of the structure.

The primary application considered for such a structure is the cooling of the leading edges and/or nose cap of a hypersonic aerospace vehicle. The embedded heat pipes remove high local heat from a leading edge and transport it to cooler aft surfaces, where it can be removed by radiation and/or active cooling. The heat pipes help to eliminate local hotspots and associated thermal gradients and stresses and to reduce peak surface temperatures of the carbon/carbon to levels within the capability of the oxidation-resisting system.

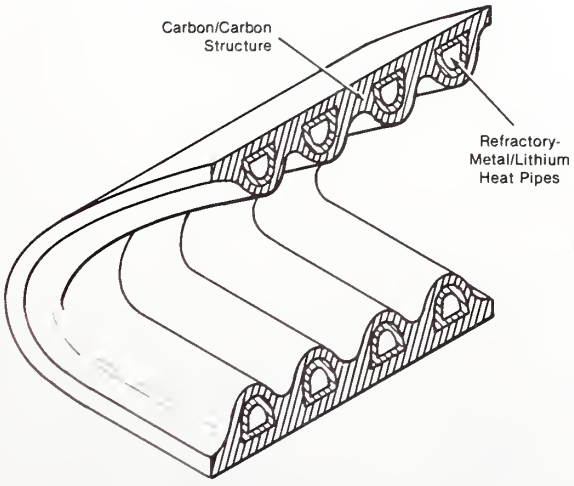
Since the maximum structural-reuse temperature of carbon/carbon [2,800 °F (1,537 °C)] is much higher than that of refractory metals [2,400 °F (1,315 °C)], or superalloys [1,800 °F (982 °C)], the carbon/carbon concept requires less area for radiation and consequently weighs much less. In addition, because carbon/carbon is structurally efficient at high temperatures, this passive design would reduce structural weight and eliminate the need for complex active cooling systems.

Since carbon/carbon is a composite material, its mechanical and thermophysical properties can be tailored to specific requirements by selection of the type of the weave and of the type and condition of the fibers. The optimum choice of properties of the composite and of the size of the heat pipes can result in a minimum-mass design that satisfies peak-temperature and thermal-stress constraints.

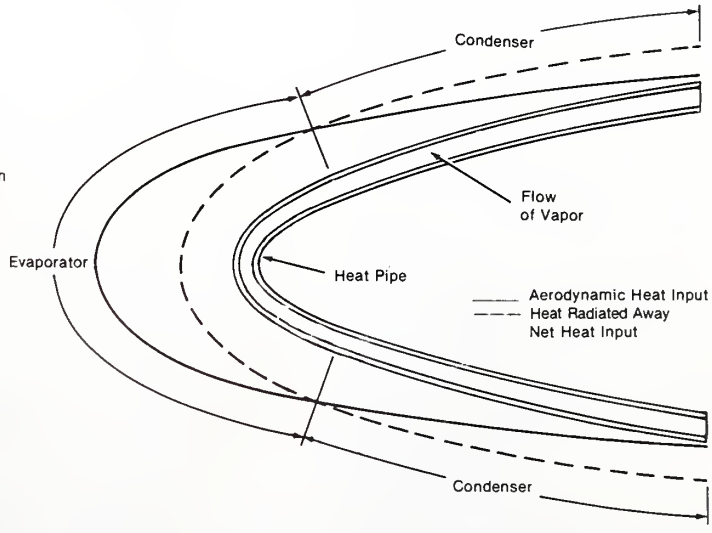
Panels can be made by laminating individual heat pipes between layers of carbon fabric to form two-dimensional reinforced carbon/carbon structural components, or the heat pipes can be incorporated into three-dimensional woven-carbon-fiber preforms by weaving the fibers around the prepositioned heat pipes. The three-dimensional approach provides much higher thermal conductivity and higher strength, which may be required to withstand thermal stresses and prevent delamination.

The most-attractive refractory metal for the fabrication of heat pipes is tungsten because of its compatibility with liquid metal working fluids, its low rate of reaction with carbon, its good mechanical and thermophysical properties at high temperature, and its low coefficient of thermal expansion. Its coefficient of expansion is close to that of carbon/carbon, thereby minimizing thermal stresses.

Since the primary application will likely involve exposure to oxidizing environ-



CARBON/CARBON LEADING EDGE CONTAINING REFRACTORY-METAL HEAT PIPES



OPERATION OF LEADING-EDGE HEAT PIPE

The **Leading Edge of a Wing** of a hypersonic airplane is cooled by metal heat pipes integrated into the carbon/carbon structure of the wing.

ments, which could rapidly consume the carbon and the refractory metal, the structures must contain systems to protect against oxidation. State-of-the-art systems of this type could protect this structure effectively, in cyclic applications, at temperatures up to 2,800 °F (1,500 °C). Coatings currently under development will extend the maximum temperature to 3,000 °F.

This work was done by Charles J. Camarda and Philip O. Ransone of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13761/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Chemical-Vapor Deposition of $Cd_{1-x}Mn_xTe$

An experimental process makes films with interesting magnetic and magneto-optical properties.

Films of the dilute magnetic semiconductor alloy $Cd_{1-x}Mn_xTe$ have been deposited on glass and GaAs substrates by metalorganic chemical-vapor deposition (MOCVD). Devices made with $Cd_{1-x}Mn_xTe$ films are known to exhibit strong photoluminescence, stimulated emission, and magnetically-tunable lasing action. In addition, the energy-band gaps of such a material can be tailored by altering its composition — a property that gives flexibility in the development of high-efficiency cascade solar photovoltaic cells.

Dilute magnetic semiconductors have been previously deposited by molecular-beam epitaxy, which requires a high vacuum. MOCVD can be performed at atmospheric pressure, resulting in more-uniform films, covering a larger area, and enabling a higher production rate.

The experimental deposition system was contained in a horizontal quartz reactor tube equipped with a graphite susceptor heated by radio-frequency energy. The source of cadmium was dimethylcadmium (DMCd) held at a temperature of 0 °C, and the source of the tellurium was diethyltellurium (DETe) at 27 °C. The DMCd and DETe were carried into the tube by highly pure H_2.

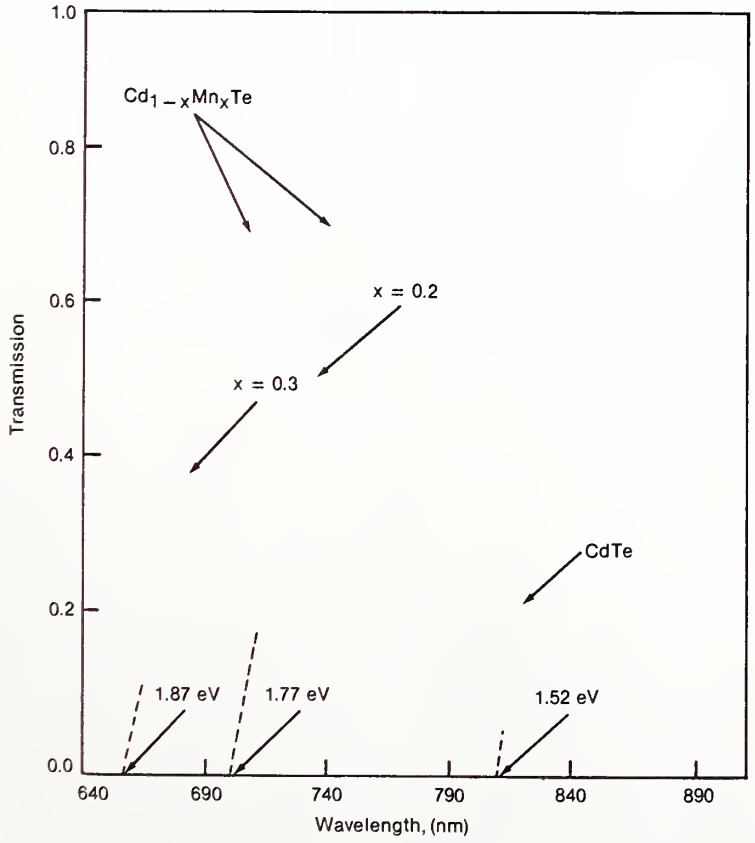

Figure 1. **The Optical Transmissions** of $Cd_{1-x}Mn_xTe$ films were measured and plotted as a function of wavelength to find the photon energy that equals the band-gap energy.

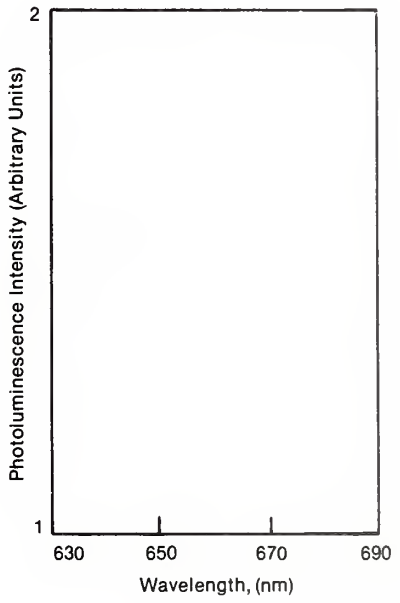

Figure 2. The **Photoluminescence Spectrum** of a specimen of $Cd_{0.75}Mn_{0.25}Te$ at a temperature of 10 K has a full width at half maximum of about 33 meV, indicating that the film has good crystalline quality.

The source of Mn was tricarbonyl(methylcyclopentadienyl) manganese (TCPMn), which is a liquid at room temperature. The hydrogen was bubbled through the TCPMn, which was heated to various temperatures between 120 and 140 °C to control the vapor pressure and, consequently, the concentration of the TCPMn. The tubes and valves carrying the TCPMn-laden H_2 and the front end of the reactor tube were heated to about 100 °C to prevent the TCPMn from condensing on them. The substrates were heated to temperatures of 410 to 450 °C, at which the metalorganic compounds decompose.

A series of depositions was made on glass substrates, and the optical transmissions were measured to determine the energy-band gaps, E_g (see Figure 1). Using the previously-known relation $E_g = 1.50 + 1.34x$ eV, it was then possible to determine

the mole fractions, x, of Mn. X-ray diffraction scans of $Cd_{1-x}Mn_xTe$ films grown by MOCVD on GaAs matched those of $Cd_{1-x}Mn_xTe$ grown on GaAs by molecular-beam epitaxy. These films exhibited strong photoluminescence at temperatures of 10 to 15 K (see Figure 2).

Although CdTe films have smooth, mirrorlike surfaces, the addition of Mn sometimes causes ripples with dimensions of a few thousand Angstroms and a hazy appearance. However, better control of process conditions should eliminate these imperfections.

This work was done by Akbar Nouhi and Richard J. Stirn of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 49 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Jet Propulsion Laboratory
Refer to NPO-17399/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Effect of Solidification Speed on Fatigue Properties

Fast solidification increases fatigue life, but the failure distribution becomes less predictable.

A report describes the effects of the rate of solidification on the nickel-based superalloy MAR-M246(Hf) used in turbine blades. The report is based on experiments in which specimens were directionally solidified at 5 cm/h and 30 cm/h, then tested for high cycle fatigue. The specimens were also inspected by energy-dispersive x-ray (EDX) analysis and optical and electron microscopy.

The specimens solidified at the higher speed had higher volume fractions of carbide and interdendritic eutectic and lower volume fractions of the γ' phase. Correlated with these characteristics was the fatigue life — twice as high in the rapidly solidified specimens as in those solidified slowly.

However, the rapidly solidified specimens failed more randomly. These specimens exhibited more early failures than did the slowly solidified specimens, which followed a normal wearout pattern. The lesser predictability of failure in the rapidly solidified specimens can be related to the greater carbide and eutectic contents. Although heat treatment can diminish the segregation to some extent, it is still greater than in the specimens solidified more slowly.

This work was done by M. H. McCay, D. D. Schmidt, W. D. Hamilton, W. S. Alter, and R. A. Parr of **Marshall Space Flight Center.** *"The Influence of Growth Rate on Fatigue Properties in a Directionally Solidified Superalloy."*

Superalloy," Circle 26 on the TSP Request Cards.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-27215/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Isothermal Equation of State for Compressed Solids

The same equation with three adjustable parameters applies to different materials.

An improved equation of state describes the pressure on a solid as a function of relative volume at constant temperature. Even though the types of interatomic interactions differ from one substance to another, the form of the equation is determined primarily by the overlap of electron wave functions during compression. Consequently, the equation is universal in the sense that it applies to a variety of substances, including ionic, metallic, covalent, and rare-gas solids. Only three parameters are needed to describe the equation for a given material.

The equation gives the pressure, P, at a fixed temperature, T, as a function of the relative size, X

$$P(X, T) = 3B_T[(1-X)/X^2] \exp[\eta_T(1-X)]$$

where B_T = the isothermal bulk modulus at zero pressure, $X = (V/V_o)^{1/3}$, V = the volume at pressure P, and V_o = the equilibrium volume (the volume at zero pressure). The parameter in the exponential term is given by

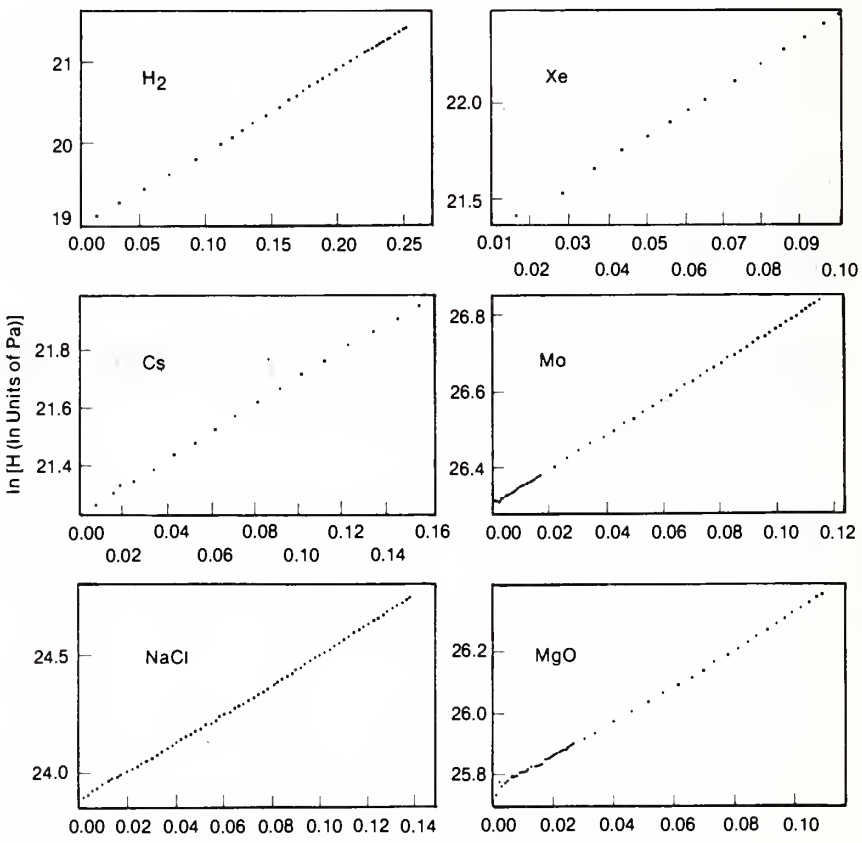
$$\eta_T = (3/2)[(\partial B/\partial P)_T - 1]$$

where B = the isothermal bulk modulus and the derivative is evaluated at zero pressure. These equations are valid over the range of pressure and volume that contains no phase changes.

To test the equation of state by comparison with experimental data, it is convenient to define a function H (not to be confused with the enthalpy, which H usually denotes in thermodynamic contexts)

$$H = \ln[PX^2/3(1-X)] = \ln(B_T) + \eta_T(1-X)$$

The pressure equation predicts that plots of experimental isothermal values of H versus $1-X$ will be linear, with intercepts and slopes yielding $\ln(B_T)$ and η_T, respectively. The prediction is confirmed by close agreement with experimental data on a variety of solids at various temperatures (see figure), including hydrogen at 4.2 K, xenon at 150 K, cesium at 295 K, molybdenum at 293 K, sodium chloride at 298 K, and magnesium oxide at 293 K.



Experimental Plots of H Versus $1-X$ all lie on nearly straight lines, even though the data in the plots were taken from measurements of different materials at different temperatures.

This work was done by Pascal Vinet and John Ferrante of **Lewis Research Center.**

Further information may be found in NASA TM-873-03 [N86-28775/NSP], Price Code: A02 "Universality in the Compressive Behavior of Solids."

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14615/TN

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National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Measuring Crack Growth Rates in Ti-6A1-4V

Tests were conducted to measure crack initiation behavior using edge notched flat specimens and short crack growth behavior was measured with specimens containing a corner notch. In addition, long crack growth behavior was measured using compact tension specimens. Methods used to attach potential leads for each type of specimen were described. All tests were conducted at room temperature. It was concluded that the potential drop technique has sufficient resolution for use as a screening tool for comparing the fatigue properties of different materials if used with appropriate techniques to compensate for inherent sources of error and that the method can play an important role in implementing damage tolerant design concepts.

Studies were carried out at NASA Lewis Research Center to determine whether the electric potential drop technique could be used to measure crack initiation and short crack growth rates in titanium turbine disc forging alloys.(2) Work described in this report was carried out using Ti-6Al-4V specimens cut from a disc forging.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield , VA 22161; (703)487-4600.

NTIS order number: N88 25937/NAC

Price code: A03.

NASA Tech Brief
National Aeronautics and Space Administration

Microencapsulated Phase-Change Materials for Storage of Heat

Investigations concentrate on the feasibility of practical, safe, lightweight systems.

A report describes research on engineering issues related to the storage and transport of heat in slurries containing phase-change materials in microscopic capsules. The specific goal of this project is to develop lightweight, compact, heat-management systems that could be used safely in the inhabited areas of spacecraft. Further development of the obvious potential of this technology can be expected to lead to commercialization and use in aircraft, electronic equipment, machinery, industrial processes, and other systems in which the requirements for the management of heat compete with severe restrictions on weight or volume.

The basic principle of operation is simple: to reduce the size and weight of a heat-transport/heat-storage system by taking advantage of the high density of the latent heat of fusion of a material that melts and freezes near the temperature of interest. Techniques that exploit this principle have been investigated since 1932. Work on the microencapsulation/slurry concept began in the early 1970's but was abandoned because of concerns over costs and the premature breakup of the capsules.

For the purposes of this investigation, the choice of materials for the slurry is dictated not only by heat-transfer characteristics but also by the requirements that the materials not be toxic, pose no fire hazard, undergo little or no change of volume in the phase change, and be chemically stable. Also of interest are the rheological properties of the slurry and the specific gravities of the components (with the consequent tendency of the capsules to separate from the liquid in the presence of gravitation and acceleration). The durability of the capsules (partly a function of size and shape and partly a function of the materials) and the costs of materials still give rise to concern as they did during the earlier investigations. A typical candidate slurry that may fulfill most of the requirements could be made of a paraffin wax in polymer capsules suspended in water. A soap or other dispersant could be added to prevent the settling or flotation of the capsules.

The investigation also addressed a number of other topics, including the following:

- Characteristics of the processes and materials used in microencapsulation;
- The storage of heat in modules containing packed beds of phase-change particles through which phase-change slurries are circulated;
- Procedures to test the slurries;
- The development of pumping systems;
- Laboratory data-gathering and experimental fluid systems; and
- The design of experiments to be flown aboard the Space Shuttle.

The achievements include the demonstration of a slurry with a thermal capacitance 10 times that of water and a heat-transfer coefficient twice that of water. An efficient phase-change heat-storage unit was designed, and it was shown that the pump work required to maintain a given overall thermal condition can be reduced as much as 90 percent below that of a comparable system based on water alone. In addition, the enhanced transport and storage of heat in a phase-change slurry take place under conditions that are nearly isothermal in comparison with those of older systems.

This work was done by David P. Colvin of Triangle Research and Development Corp. for **Marshall Space Flight Center.** *"Investigation and Development of a Phase Change Thermal Energy Storage System Using Microencapsulated Phase Change Materials."*
MFS-27198/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

Robot Hand Grips Cylinders Securely

Jaws and linkage accommodate various sizes.

A robot hand includes two pairs of parallel jaws that can grasp rods, pipes, tubes, struts, and other long, heavy cylindrical objects. The hand features a compact rotary drive and a butterfly configuration that simplify the approach and gripping maneuvers of the robot.

Parallelogram linkages maintain the alignment of each jaw with the other jaws. One bar of each linkage is connected to one of two concentric, counterrotating shafts; the rotation of these shafts moves the jaws in each pair toward or away from each other to grasp or release the workpiece (see Figure 1).

Each jaw includes a rigid gripping pad lined with rubber to give it a firm grip and to prevent damage to the workpiece. The inner cylindrical surface (corner) of each jaw tapers off to flat sides. This enables the jaw to grasp workpieces with diameters larger than or equal to twice the corner radius. The range of graspable diameters could be increased by making the corner radius very small and the flat sides as fingers that mesh together when the jaws approach each other.

The counterrotating shafts are driven by two pancake-type harmonic speed reducers in series, actuated by the same motor (see Figure 2). The output of one harmonic speed reducer drives the inner shaft, while that of the other harmonic speed reducer drives the outer shaft. Slots are cut in the outer shaft so that the stationary portions of the harmonic speed reducers can be fixed to the housing. It is possible to do this because the outer shaft does not have to rotate more than 50°.

This work was done by George F. Parma of **Johnson Space Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center. Refer to MSC-21365/TN.

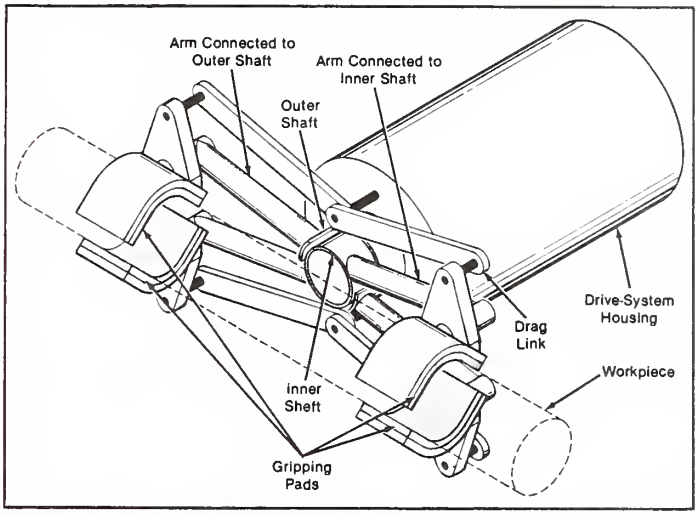

Figure 1. **Pairs of Jaws on Parallelogram Linkages** are actuated by counterrotating shafts. Part of the outer shaft is cut away to allow movement of the arms of the linkage connected to the inner shaft.

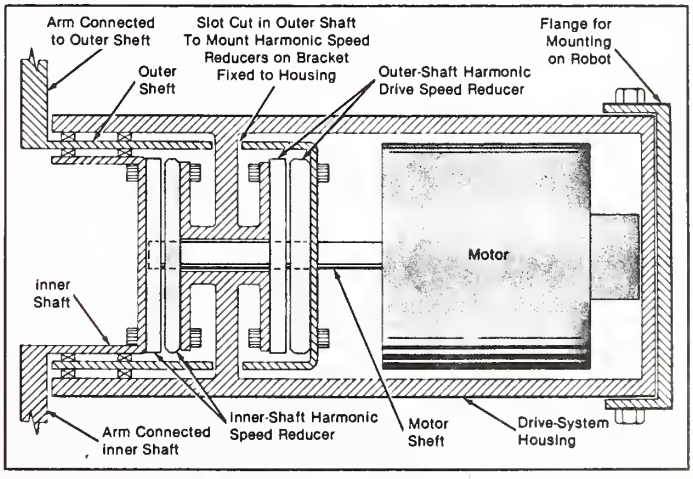
Arm Connected to Outer Sheft
Slot Cut in Outer Shaft To Mount Harmonic Speed Reducers on Bracket Fixed to Housing
Flange for Mounting on Robot
Outer Sheft
Outer-Shaft Harmonic Drive Speed Reducer
Motor
inner Shaft
Arm Connected inner Shaft
Inner-Shaft Harmonic Speed Reducer
Motor Sheft
Drive-System Housing

Figure 2. The **Compact Rotary Drive** contains two collinear harmonic speed reducers driven by the same motor.

Lyndon B. Johnson Space Center
Technology Utilization Officer: Dean C. Glenn
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(713) 483-3809
Patent Counsel:
Edward K. Fein
Mail Code AL3
Houston, TX 77058
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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Thermal Analysis of Reluctant Glass Formers

A thermocouple holds a sample and monitors its temperature during cooling.

An apparatus for the study of heterogeneous nucleation and crystallization in reluctant glass formers achieves cooling rates from 10 to 2,500 °C/s by providing control of both radiative and conductive cooling. Reluctant glass formers are materials that require cooling rates greater than 10 °C/s to form glasses. Laser spin melting, a prior technique, can be used only at cooling rates greater than about 1,000 °C/s and only for very small samples. The new apparatus can be used to examine the glass-formation ability of a material and the critical cooling rate to form a glass from it.

The apparatus (see Figure 1) includes an ellipsoidal furnace, which focuses radiation from a tungsten/halogen lamp onto a sample. The sample is supported between the two leads of a type S thermocouple that has a junction bead 0.005 in. (0.13 mm) in diameter. Raising the power to the lamp melts the sample, causing it to flow around the thermocouple bead. A specimen in a still atmosphere can be cooled at rates from 10 to 250 °C/s by reducing the lamp power at the appropriate rate with a variable-speed, motor-driven, adjustable transformer. Higher cooling rates are obtained by blowing helium gas onto the sample after turning the lamp off.

The temperature of the sample is derived from the thermocouple signal. During quenching, the temperature of the sample is recorded on a strip chart and/or in a microcomputer data-acquisition system. The recorded quenching curve (see Figure 2) is analyzed to determine the temperature of the sample prior to quenching; the rate of cooling prior to nucleation; the time and temperature of nucleation; the rate, time, and temperature of recalescence; and the rate of cooling after nucleation.

Quenched samples are inspected for crystallization. If the quenched sample is transparent and the quench curve shows no recalescence peak, it is assumed that glass has been formed. Whenever a recalescence peak is observed, the sample is opaque and predominately crystalline due to the rapid rate of crystal growth.

Nucleation times and temperatures for a large number of different quenches can be plotted to produce empirical continuous-cooling-crystallization diagrams. The nucleation of crystallization from each

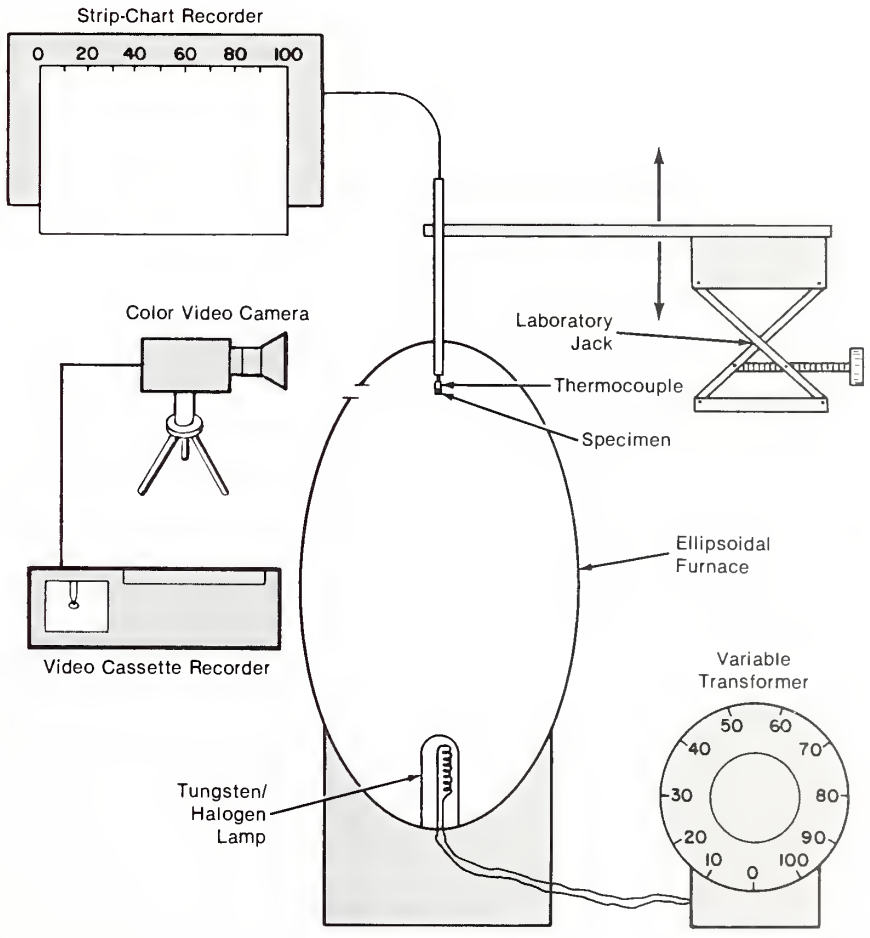

Figure 1. The **Ellipsoidal Furnace** provides controlled cooling rates for studies of the thermal properties of reluctant glass formers. A glass tube (not shown) is inserted into the furnace and used to blow helium on the specimen to cool it rapidly.

quench run that did not result in the formation of glass is represented by a datum on the plot.

This work was done by Edwin C. Ethridge and Peter A. Curreri of **Marshall Space Flight Center.** *MFS-28283/TN*

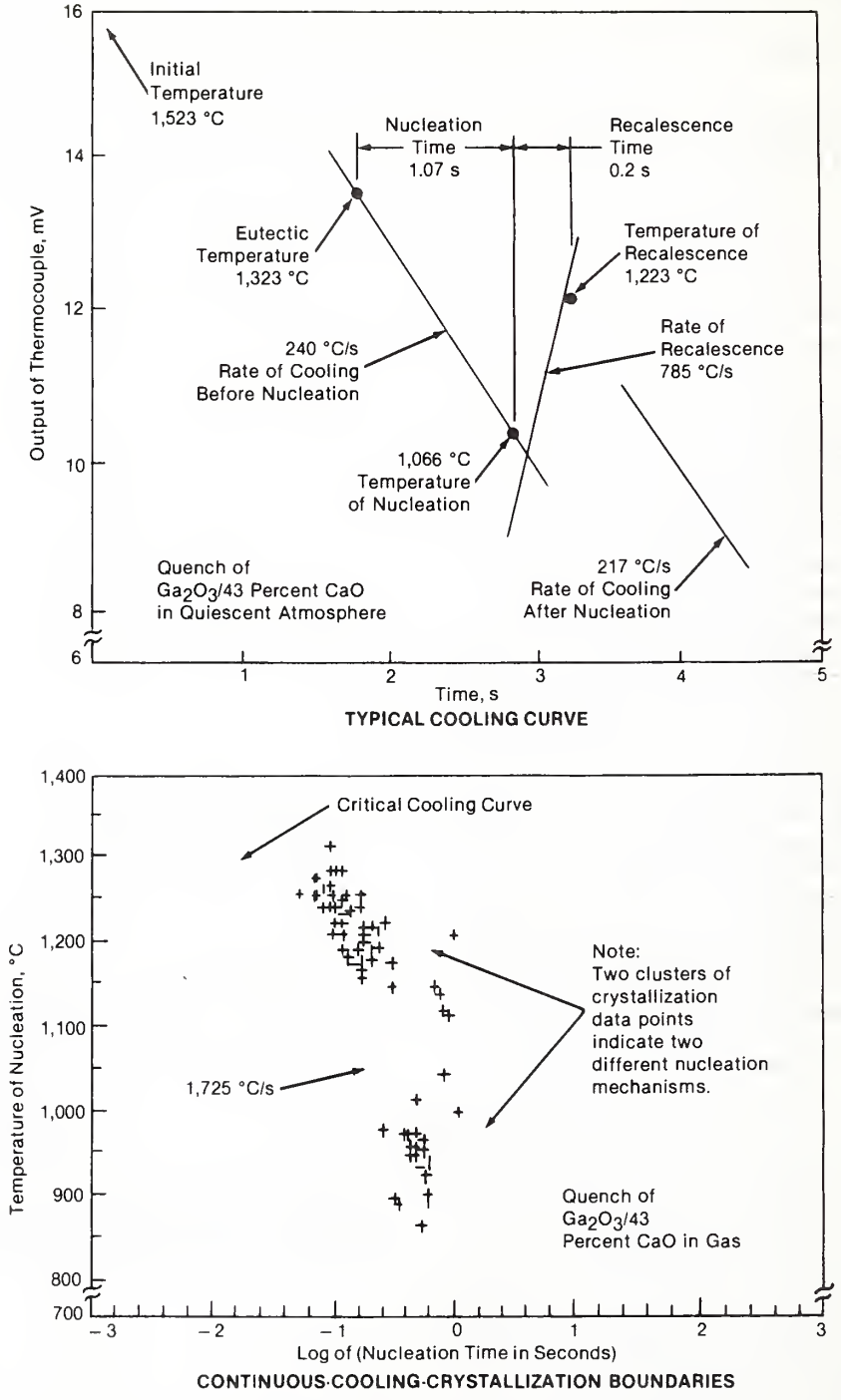
Initial Temperature 1,523 °C
Nucleation Time 1.07 s
Recalescence Time 0.2 s
Eutectic Temperature 1,323 °C
Temperature of Recalescence 1,223 °C
240 °C/s Rate of Cooling Before Nucleation
Rate of Recalescence 785 °C/s
1,066 °C Temperature of Nucleation
Quench of Ga_2O_3/43 Percent CaO in Quiescent Atmosphere
217 °C/s Rate of Cooling After Nucleation
Output of Thermocouple, mV
Time, s
TYPICAL COOLING CURVE
Critical Cooling Curve
Note: Two clusters of crystallization data points indicate two different nucleation mechanisms.
1,725 °C/s
Quench of Ga_2O_3/43 Percent CaO in Gas
Temperature of Nucleation, °C
Log of (Nucleation Time in Seconds)
CONTINUOUS-COOLING-CRYSTALLIZATION BOUNDARIES

Figure 2. A **Cooling Curve** (above) can be analyzed to determine the rate of cooling and such properties of the sample as nucleation and recalescence temperatures at that cooling rate. Continuous-cooling-crystallization boundaries can be determined empirically from plots of nucleation time vs. nucleation temperature from runs at a large number of different rates of cooling.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and
Space Administration

Quality Evaluation by Acousto-Ultrasonic Testing of Composites

This promising nondestructive-testing method is based on ultrasonic simulation of stress waves.

A report reviews acousto-ultrasonic technology for nondestructive testing. The report discusses principles, suggests advanced signal-analysis schemes for development, and presents potential applications.

Acousto-ultrasonics has been applied principally to assess defects in laminated and filament-wound fiber-reinforced composite materials. The technique can be used to determine variations in such properties as tensile, shear, and flexural strengths and reductions in strength and toughness caused by defects. It can be used to evaluate states of cure, porosities, orientation of fibers, volume fractions of fibers, bonding between fibers and matrices, and qualities of interlaminar bonds.

The term "acousto-ultrasonics" is a contraction for "acoustic-emission simulation with ultrasonic sources." Conventional acoustic-emission testing depends on loading a part to excite spontaneous stress waves like those that accompany plastic deformations and the growth of cracks. Acousto-ultrasonics differs mainly in that the ultrasonic waves are benign and are generated externally by pulsed sources (usually piezotransducers).

In a typical apparatus, a transmitting probe and a receiving probe are placed a specified distance apart on the same side of the part under test. The sending-and-receiving pair can be moved about as a unit to scan the part. Signal-processing instrumentation analyzes the received sound to generate a map of variations in the properties of the material.

The sensitivity of acousto-ultrasonics has already been demonstrated experimentally. The technology has been used to detect and quantify subtle but significant variations in strength and resistance to fracture of fiber-reinforced composites. This achievement is remarkable because it was accomplished with relatively-unsophisticated signal-processing and signal-analysis procedures.

Although acousto-ultrasonic technology has been used on polymer-matrix composites, it is applicable to such other composite materials as metals reinforced by fibers and ceramic-matrix composites. The use of acousto-ultrasonics should be considered whenever it is necessary to quantify damage or degradation of properties after composites have been exposed to hostile environments.

This work was done by Alex Vary of **Lewis Research Center**. *Further information may be found in NASA TM-89843 [N87-20562], Price Code A03 "The Acousto-Ultrasonic Approach."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14709/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Medicine & Biology

1078 Audiovisual Services at the Wisconsin Regional Primate Center

1079 Platinized Chloroplast: A New Bioelectronic Material

1080 Active People May Need Extra Protein

1081 Registry of Comparative Pathology

1082 Research Animal Diagnostic and Investigative Laboratory

1083 Resource for the Study of Laboratory Animal Diseases

1084 Depth Perception in Remote Stereoscopic Viewing Systems—A viewing strategy accommodates the competing requirements of low distortion and high resolution.

Other Items of Interest

1010 Image-Enhancement Aid for the Partially Sighted—Digital filtering would enhance the ability to read and to recognize objects.

1046 "Hazard I" Released to Help Reduce Fire Deaths and Costs

Federal Laboratory Resource

NIH Research & Technology

U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Audiovisual Services at The Wisconsin Regional Primate Center

The Wisconsin Regional Primate Research Center (WRPRC) in Madison has made a commitment through programs, staffing, and internal support to collect, preserve and disseminate audiovisual materials on nonhuman primates. The center's library is building archives of videotape and audiotape materials that will preserve the behavioral and vocal repertoire of all nonhuman primates, particularly those designated as threatened or endangered.

"A critical concern among primatologists and others worldwide is the question of endangered and threatened nonhuman primates. Loss of natural habitats, poaching, and unenlightened management of resources have put many nonhuman primates—Africa's mountain gorillas, the orangutans in Asia, and the lemurs of Madagascar—on the verge of extinction," says Larry Jacobsen, director of the WRPRC library.

Among the libraries serving the seven Regional Primate Research Centers funded by the Animal Resources Program of the NIH Division of Research Resources, the Wisconsin library has taken an active role in the collection and dissemination of behavioral research data stored on videotape and audiotape.

Established in 1973, the center library has evolved from a small room with 400 monographs into an important na-

Robert Dodsworth

Larry Jacobsen (left), head librarian at the Wisconsin Regional Primate Research Center, and Ray Hamel, special collections librarian, review videotaped footage of rhesus monkeys. The library is building archives of audiovisual materials on nonhuman primates; the materials are available for loan.

tional resource with 30,000 items, including periodicals, monographs, slides, videotapes, and sound recordings. The audiovisual collection features nearly 4,000 slides and videotapes. Its scope includes living and fossil primates, primatology, primate facilities, veterinary and animal husbandry, research methods, and zoo housing. Master copies of materials in the collection are stored in a temperature-controlled environment to protect them from long-term deterioration.

The WRPRC library continues to make a strong commitment to outreach and to the support of scientific research, teaching, and conservation. All items in the collection are made available for loan unless otherwise specified by the contributor. According to Ray Hamel, special collections librarian, the library loaned more than 500 items in 1987 and nearly double that number in 1988.

One of their most requested items is a set of slides and a videotape developed by Dr. Viktor Reinhardt and Robert Dodsworth of the WRPRC showing environmental enrichment for caged rhesus monkeys. Great interest has been shown in this material because of the current development of new regulations that will govern how animals should be kept in confinement or laboratory situations.

Materials in the collection are catalogued, indexed, and entered into a computer data base. Items are conveniently retrievable by family, genus, species, common name, sex, age, captive or noncaptive status, and subject matter. Data base searches can be carried out for materials in the library collection and available from other sources. Some searches or loans may be subject to a minimal service fee.

To inform contributors and borrowers of new items in the collection, the library publishes the bimonthly *Primate Library Report: Print Acquisitions* and the semiannual *Primate Library Report: Audiovisual Acquisitions*. The audiovisual newsletter is distributed to more than 700 readers including most members of the American Primatological Society, selected zoos and libraries, and other interested individuals.

In building the collection, the Center has relied on contributions from primatologists throughout the United States and abroad. In an effort to continue expanding the scope of the collection, the library is seeking videotapes, films, or slides showing: pelage (hairy coat) or other taxonomic features; sexual dimorphism; social and/or family groupings; behaviors such as play, sex, and feeding; facial expression; habitat; and aging and growth-related changes.

Mr. Jacobsen notes the critical need to develop and disseminate materials that will serve both the present research and educational community and at the same time provide an archival record.

"This is one of the few places in the world where a systematic attempt is being made to collect and preserve the unique records that will give future generations an opportunity to experience the great variety of species that make up the primate order. Sadly, many historical materials have been lost or lie unmanaged," he says. "New technology increasingly enables individuals to make an audiovisual record, but unless they are encouraged to preserve their work, a great deal of vital information will be lost."

For more information about audiovisual services at WRPRC, contact:

Mr. Larry Jacobsen, Head Librarian
Wisconsin Regional Primate Research Center
University of Wisconsin
1223 Capitol Court
Madison, Wisconsin 53715
Telephone: (608) 263-3512/ 263-3852

For Additional Information:

To locate information or professional contacts on this effort, contact:

Research Resources Information Center
1601 Research Boulevard
Rockville, MD 20850
(301) 984-2870

Department of Energy

Technology Application

Oak Ridge National Laboratories

Platinized Chloroplast: A New Bioelectronic Material

When plants photosynthesize carbohydrates from carbon dioxide and water, an elaborate electron-transport system links the two light-activated reactions that drive the process. In addition to its electrical properties as a metal, platinum is a highly efficient cathode for the electrosynthesis of hydrogen. In a new bioelectronic system developed at ORNL, colloidal platinum precipitated onto the surface of a spinach-derived, photosynthetic thylakoid membrane short circuits the transfer of electrons and splits water, yielding hydrogen and oxygen instead of a carbohydrate and oxygen. This material, called "platinized chloroplast," was discovered in a search for photosynthetic methods of producing hydrogen fuel from water. This new development has successfully combined approaches from the field of biotechnology with the nonbiological methods of molecular engineering.

Data on the platinized chloroplast system demonstrate that charge continuity is maintained during electron flow across the membrane-metal interface (Fig. 1). The moistened platinized chloroplast is capable of sustained simultaneous photoevolution of hydrogen and oxygen when irradiated with any wavelength of light in the chlorophyll absorption spectrum.

In determining which specific ionic species could be used for preparing the bioelectronic material, additional information was acquired about the electrostatic properties of the photosystem I reduction site on the membrane surface. Hydrogen was produced when platinum

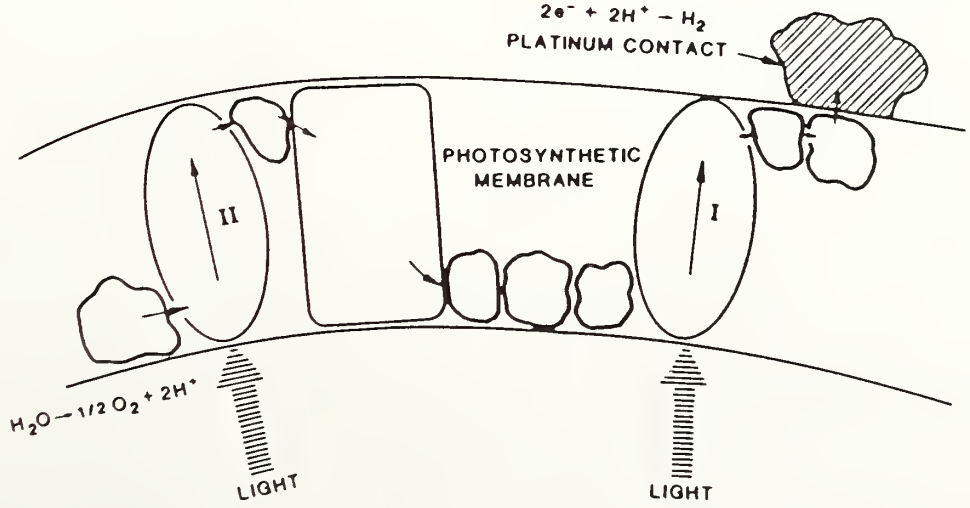

Fig. 1. Photosynthesis consists of two light reections, photosystems I and II, which ere linked in series by en electron-transport chain. The photosystems, as well as the electron-transport chain, are embedded in e thin membrane (70 Å thick), which also contains the light-harvesting chlorophyll molecules. In normel photosynthesis, the electrons emerge from the membrene and flow to the Calvin cycle enzymes for the chemical reduction of carbon dioxide to carbohydrate. The platinum contact short circuits the electron flow and serves as an electrode for the photoelectrosynthesis of hydrogen from weter.

was precipitated from the hexachloroplatinate(IV) ion, which bears a net negative charge (−2). When platinum was precipitated from the positively charged (+2) tetraammineplatinum(II), no hydrogen activity was detected. This result suggests that the positively charged ion is repelled by the photosystem I reduction site, which presumably bears a net local positive electrostatic charge. This interpretation is logical considering that the protein amino acid composition in the vicinity of photosystem I is rich in lysine residues, which would be positively charged at physiological pH.

Initially, the conventional method (treating an aqueous salt solution of the metal with a chemical reductant) was used for precipitating elemental platinum onto a substrate to prepare platinized chloroplasts (i.e., treating an aqueous salt solution of the metal with a chemical reductant). This method of platinizing chloroplasts has the unique advantage of depositing the metal colloid particle at the site of electron emergence from the thylakoid membrane; thus, the particle can serve as a marker for the photosystem I reduction site.

Platinized chloroplasts are an example of an artificial photosynthetic material in which the energy-rich product is molecular hydrogen rather than a carbon dioxide fixation compound (the normal product of photosynthesis). A near-term goal of research in ORNL's Chemical Technology Division is to effect other energy conversion reactions, such as the synthesis of ammonia or methane, by contacting selected metals and catalysts with the energy-rich electrons emerging from the photosynthetic membrane. Photoreactions of this type are clearly of scientific interest for the production of fuels and chemical feedstocks from renewable organic resources.

U.S. Patent Number 4,657,646, *Method of Producing Metallized Chloroplasts and Use Thereof in the Production of Hydrogen and Oxygen,* has been granted for this invention.

Additional information:

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257

Telephone: (615) 574-4192; FTS 624-4192

E. Greenbaum, "Platinized Chloroplasts: A Novel Photocatalytic Material," *Science* **230** 4732, 1373-75 (December 20, 1985).

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Active People May Need Extra Protein

Everyone knows that a physically active person needs more calories than a sedentary soul, unless the active person wants to lose weight. But is the same true for protein? For years, the experts thought not—even though protein is the raw material of muscle and sinew.

According to the National Research Council, which establishes the U.S. Recommended Dietary Allowances, there is "little evidence that muscular activity increases the need for protein." And the World Health Organization stated that "energy requirements change with activity and lifestyle [but] protein requirements do not."

Both organizations had based their daily protein recommendation primarily on studies of sedentary men and women.

However, since more and more people now engage in regular exercise, a group of physiologists at USDA's Human Nutrition Research Center on Aging at Tufts University decided to reexamine the relationship between dietary protein and exercise.

"There was evidence that a single bout of endurance exercise increased the body's breakdown and loss of proteins," says Carol N. Meredith, who led the study. "We wanted to see if people who were already adjusted to endurance exercise need more than the current RDA."

Meredith, who is now with the University of California at Davis, and her colleagues selected 12 very active men who had been running, cycling or rowing for at least 2 years.

Half of the men were in their fifties and half in their twenties because "we also wanted to see if age had any effect on protein requirements," she says. As it turned out, age didn't correlate with increased protein loss, but endurance exercise did.

The men's minimum daily requirement, averaging 0.94 grams per kilogram (about 1.5 ounces per 100 pounds of body weight), turned out to be higher than the RDA of 0.8 g/kg, which has a built-in cushion to cover the needs of nearly everyone, says Meredith. "With a similar cushion added to our value for active men, their recommended intake would be 1.25 g/kg—or about 60 percent more than the RDA," she says. (This would equal 2.03 ounces of protein per 100 pounds.)

The results did not explain why they need more, however, even though the most obvious possibilities were tested.

Fortunately, says Meredith, most men living in the United States—including the fitness zealots—don't have to worry about getting enough protein.

The average protein intake for men, according to the 1985 USDA food consumption survey, is 75 percent above the RDA. Women's average intake is 34 percent above the RDA.

No studies have been done to determine how much protein endurance-trained women need, she says.

However, certain athletes—gymnasts, wrestlers, dancers, skaters—frequently restrict their food intake to stay slim, she adds. In the process, they may be shorting themselves of needed protein.

Also, women athletes tend to diet frequently. "If they require more protein than sedentary women, they may not be getting enough from the little they eat."

Carol N. Meredith is now with the Division of Clinical Nutrition, University of California, TB 156, Davis, CA (916) 752-6778. ◆

NIH
Research & Technology
Federal Laboratory Resource
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Registry of Comparative Pathology

Principal Investigator:
Dante G. Scarpelli, M.D., Ph.D.
Northwestern University
303 East Chicago Avenue
Chicago, Illinois 60611
(312) 908-8144

The reference center is located in the Armed Forces Institute of Pathology (AFIP) on the campus of the Walter Reed Army Medical Center in Washington, D.C. The center is administered jointly by Universities Associated for Research and Education in Pathology (UAREP) and the AFIP.

Its registry advisory committee is chaired by Dr. Dante Scarpelli, professor and chairman of the pathology department at Northwestern University Medical School in Chicago, and includes outstanding pathologists who have special experience and interest in comparative pathology.

Resources Provided

- *Reference Services:* The registry maintains increasing collections of tissue and illustrative material, all indexed in a "natural language" computerized file and available for study. Scientists can use materials for research training, research, or preparation for teaching. Registry personnel conduct workshops, symposia, and short courses, prepare exhibits, and loan study sets and syllabi. A listing of the registry's study sets is contained in the *List of Education Aids* of the Armed Forces Institute of Pathology. The registry publishes *Comparative Pathology Bulletin*; *Handbook: Animal Models of Human Diseases*; and *Educational Opportunities in Comparative Pathology, U.S. and Foreign Countries*. Principal types of service requests include: animal models for specific animal species; specific information about diseases in animals, methodology, training, and career opportunities.
- *Consultation Available:* Consultation is available on histopathology of all animal cases of interest from a comparative standpoint, especially those that may have implications regarding human disease or models of human disease. Service is provided to investigators on a cooperative basis.
- *Contact Person:* George Migaki, D.V.M., Armed Forces Institute of Pathology, Washington, D.C., (202) 576-2452.

Research Emphasis or Application

- *Basic Objectives:* To collect, classify, and study diseases of comparative pathology interest. To utilize knowledge of diseases in many animal species in order to benefit humanity.

Federal Laboratory Resource

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Research Animal Diagnostic and Investigative Laboratory

Principal Investigator
Joseph E. Wagner, D.V.M., Ph.D.
Research Animal Diagnostic and Investigative Laboratory
College of Veterinary Medicine
University of Missouri
Columbia, Missouri 65211
(314) 882-6647

Resources Provided

- *Diagnostic Services:* This laboratory is staffed to provide competence in gross and microscopic pathology, microbiology, parasitology, and rodent serology. Diagnostic resources are designed primarily to serve the grantee and affiliated institutions as well as regional users of animals in human health-related research. Faculty members and staff are available for collaboration in investigating laboratory animal disease problems.
- *Postdoctoral Training in Laboratory Animal Medicine and Pathology:* This laboratory provides training for graduate veterinarians in laboratory animal medicine and pathology. Stipends are from Federal, state, and private sources. The program is designed to prepare candidates for the certifying examination of the American College of Laboratory Animal Medicine (ACLAM). Persons with a B.S. in biology may work toward an M.S. in microbiology with emphasis on bench microbiology and applied serodiagnostics in support of research animal quality assurance.
- *Contact Persons:* Joseph E. Wagner, D.V.M., Ph.D., (314) 882-6647, Earl K. Steffen, Ph.D., (314) 882-5996; Cynthia L. Besch-Williford, D.V.M., Ph.D., (314) 882-5998, or Lela K. Riley, Ph.D., (314) 882-2029.

Research Emphasis or Application

- *Basic Objectives.* To aid in maintaining the quality of research animals through control and diagnosis of diseases within the research animal facilities at the University of Missouri campuses in Columbia, St. Louis, Kansas City, and Rolla, and other regional medical research facilities. To recognize and define abnormal physiologic conditions and comparative diseases that may be of interest to biomedical researchers.
- *Current Research:* Naturally occurring diseases of laboratory animals; *Mycoplasma* spp. from rodents; development of ELISA and other serodiagnostic tests for *Mycoplasma* spp., Tyzzer's disease, and murine viruses; establishment and translocation of enteric flora; mutant inner ear disease of rats; viral infections of hamsters; mechanisms of infection with intracellular bacterial pathogens, including *Bacillus piliformis* and *Campylobacter* spp., of laboratory animals; nasal dermatitis of gerbils; cytauxzoonosis of cats; and control of aggression in male mice.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Federal Laboratory Resource

Resource for the Study of Laboratory Animal Diseases

Principal Investigator:
Robert O. Jacoby, D.V.M., Ph.D.
Yale University School of Medicine
P. O. Box 3333
333 Cedar Street
New Haven, Connecticut 06510
(203) 785-2525

Resources Provided

- *Diagnostic Services:* This laboratory is staffed to provide general competence in gross, microscopic, and ultrastructural pathology, microbiology, parasitology, and hematology and has special expertise in viral diseases of rodents. Diagnostic resources are designed primarily to serve the grantee and affiliated institutions. However, with approval by the principal investigator, they are available for collaboration in investigating laboratory animal disease problems.
- *Contact Person:* Robert O. Jacoby, D.V.M., Ph.D., (203) 785-2525.

Research Emphasis or Application

- *Basic Objectives:* To maintain the quality of research animals through control and diagnosis of diseases within animal research facilities at the Yale University School of Medicine. To recognize and define conditions and diseases that may be of interest to biomedical research.
- *Current Research:* Improved methods for detection of murine viral infections; pathobiology of mousepox, mouse hepatitis virus, and rodent parvovirus infections; genetic factors controlling resistance and susceptibility to Sendai viral pneumonia; mechanisms of persistence in viral infection of rodents; immunosuppression induced by murine viruses; animal model of Lyme disease; animal models of osteoporosis.

NASA Tech Brief
National Aeronautics and Space Administration

Depth Perception in Remote Stereoscopic Viewing Systems

A viewing strategy accommodates the competing requirements of low distortion and high resolution.

A report describes theoretical and experimental studies of the perception of depth by human operators through stereoscopic video systems. The purpose of such studies is to optimize dual-camera configurations used to view the workspaces of remote manipulators at distances of 1 to 3 m from the cameras. On the basis of their findings, the authors propose a strategy that minimizes the stereoscopic depth distortion without sacrificing stereoscopic depth resolution.

To provide high depth resolution with adequate overlap of the stereo image pairs, the viewing axes of the cameras are made to converge on the point of interest. As the intercamera distance increases, the depth resolution increases, but so does the depth distortion. Conversely, the depth distortion can be reduced by decreasing the distance between cameras, but depth resolution is decreased. Heretofore, some researchers have advocated orthostereoscopic camera alignments (those that imitate natural human viewing conditions), while others have advocated hyperstereoscopic alignments (those with unnaturally-large camera separations).

The authors note that the small-angle approximations used in most previous analyses obscured the relationship between the stereoscopic distortion and the major parameters of the camera configurations. To explore this relationship more fully, they present a rigorous geometric analysis without small-angle approximations. They also ask whether human observers' responses follow the predictions of the geometric analysis despite internal human perceptual corrections and distortions.

Experiments were performed to answer the latter question. Human observers used a Honeywell (or equivalent) field-sequential stereoscopic viewing system and viewed two vertical rods through two television cameras. One rod was placed at a distance of 1.3 m from the line between the cameras; the other was placed at various distances a few centimeters closer or farther than 1.3 m. In one set of experiments, the cameras were translated to different distances along the line between them. In another set of experiments, the cameras were rotated about a point between them. In all the experiments, the observers were asked to report their perceptions of which of the two rods appeared closer to the viewer.

The experimental results show that although uncertainties in depth perception vary among observers, the perceived depth distortions follow the predictions of the geometric analysis. Thus, the observers' internal corrections and distortions do not invalidate the usefulness of the geometric analysis in the prediction of optimal camera configurations.

According to this analysis, the static stereoscopic depth distortion can be decreased, without decreasing the stereoscopic depth resolution, by increasing the camera-to-object and intercamera distances and the camera focal length. The analysis further predicts that the dynamic stereoscopic depth distortion can be reduced by rotating the cameras around the center of the circle (the Vieth-Mueller circle) that passes through the point of convergence of the viewing axes and the first nodal points of the two camera lenses.

This work was done by Daniel B. Diner and Marika von Sydow of Caltech for **NASA's Jet Propulsion Laboratory.** *"Stereo Depth Distortions in Teleoperation."* *NPO-17118/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Natural Resources Technology & Engineering

Software

1085 Computer Program for Detecting or Predicting Fracture Zones

Testing & Instrumentation

1086 Composition of Earth Studied with Custom Technique

New Technology

U.S. Department of the Interior Bureau of Mines

Computer Program for Detecting or Predicting Fracture Zones

Objective

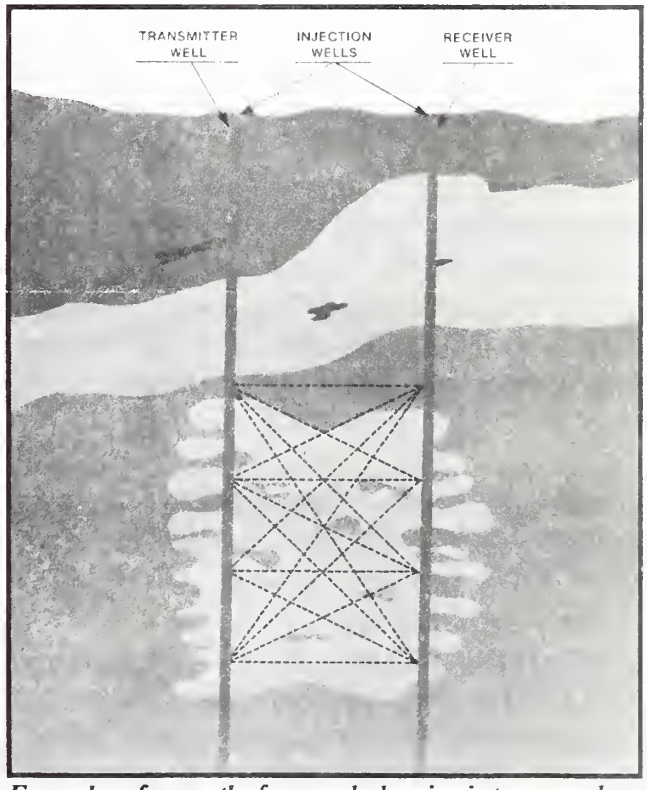
Develop a means for analyzing seismic crosshole data to predict and monitor the flow of leach solution during in situ mining.

Background

Improvements in predicting and monitoring in situ leach solution flow would aid in planning well field configurations. These improvements would also facilitate permit application by assuring regulatory agencies that leach solution would not escape from a well field undetected. Seismic tomography can detect fractured zones, which enables the prediction of probable flow paths, and it is a promising technique for monitoring leach solution injected above the water table. Tomographic analysis of crosshole seismic data provides a two-dimensional picture of the distribution of seismic velocities between the transmitter and receiver boreholes. The positions of fractured zones and of leach solution can then be inferred from the seismic velocities.

The Problem

To perform tomographic analysis, the area between the transmitter and receiver boreholes is mathematically divided into small elements called pixels. Tomography determines what distribution of seismic velocities among the pixels yields the best fit to travel times for the many paths crossing the area. Tomographic analysis of crosshole data without constraints does not yield a unique reconstruction, even with more measurements than pixels. Crosshole data can be fit equally well by many different reconstructions, so appropriate mathematical constraints must be applied to help select the correct one. A tomographic program providing a test for nonuniqueness and constraints to counteract nonuniqueness was needed. Commercially available programs did not provide such a test nor constraints appropri-



Examples of ray paths for crosshole seismic tomography.

ate for in situ mining applications.

Approach

The U.S. Bureau of Mines developed a tomographic computer program (BOMTOM--Bureau of Mines tomography) with a test for uniqueness and constraints to help obtain unique reconstructions. The program is easy to run on personal computers commonly used by mining companies and others. Options can be selected interactively. BOMTOM uses a simultaneous iterative reconstruction technique. It uses straight ray paths because the seismic velocity contrasts in an in situ mining operation are unlikely to be great enough to require curved ray analysis.

Tests and Constraints

BOMTOM allows the user to test uniqueness by varying the pattern of the initial velocity guesses used to start the iterative solution procedure. A unique reconstruction is independent of the initial velocity guesses.

BOMTOM provides the following options for constraints:

1. Maximum and minimum calculated velocities.

2. Known, fixed velocities in boreholes, such as from sonic logs.

3. Horizontal layers near the top and/or bottom of the investigated area in which seismic velocity does not vary with horizontal position.

4. Smoothing, in which the calculated velocity in a pixel is influenced by the velocities in neighboring pixels.

Other Applications

BOMTOM has been used for detecting zones of fractures in quarries by analyzing seismic refraction data. The velocity contrast in quarries is large enough to make curved ray analysis desirable. BOMTOM has also been used for examining building stone by analyzing seismic travel times for two pairs of faces to detect fractures that are not visible from the surface.

For More Information

U.S. Bureau of Mines Report of Investigations (RI) 9159, by D.R. Tweeton, describes BOMTOM and results of testing the effectiveness of various combinations of constraints in obtaining unique reconstructions when simulating in situ mining. A free single copy of this report may be obtained by writing to the Bureau's Publication Distribution Section, P.O. Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236.

The application to detection zones of fractures in quarries is described in "Application of Refraction Tomography to Map the Extent of Blast-Induced Fracturing," by C.L. Cumerlato, V.J. Stachura, and D.R. Tweeton, in "Key Questions in Rock Mechanics: Proceedings of the 29th U.S. Symposium (Minneapolis, MN, June 13-15, 1988). Balkema, 1988, pp. 691-698.

BOMTOM Features

Test of uniqueness of reconstructions.
Optional constraints to counteract nonuniqueness.
- **Maximum and minimum velocities.**
- **Fixed velocity in boreholes.**
- **Horizontal layers with uniform velocity.**
- **Smoothing.**

Other options.
- **Comparisons with prior runs.**
- **Generation of synthetic data.**

Ease of use.
- **Runs on personal computer.**
- **Interactive setting of options.**

Source and executable codes in FORTRAN and QuickBasic on 5-1/4 and 3-1/2 inch IBM-compatible diskettes are available from D.R. Tweeton, U.S. Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Avenue South, Minneapolis, MN 55417 (612/725-4670).

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Composition of Earth Studied with Custom Technique

Using a custom-made chemical measurement system, researchers at NIST are helping to unlock secrets about the earth's composition, evaluating the origins of precious metal ores, and determining the contributions of extraterrestrial material to the earth's makeup. At the heart of the NIST-developed system is a powerful technique known as resonance ionization mass spectrometry (RIMS). Among other things, RIMS enables scientists to measure rhenium and osmium, two difficult-to-detect elements found in the earth's rocks. By gauging the abundance of these two elements in a rock sample, scientists can determine the age of a rock and learn much about the history of the earth at the site where the sample was taken. The RIMS technique of measuring rhenium and osmium has been used successfully in studies that examine how deposits of platinum, gold, and other precious metals were created. For example, the method played a key role in a study showing that the movement of water mobilized certain components of very old rocks, creating gold deposits in the Kolar Region of India. RIMS also has been employed for other types of chemical analyses, such as measuring impurities in the thin films that coat semiconductors.

FOR ADDITIONAL INFORMATION: To discuss these efforts further, contact Dr. Jack Fassett, Physics Building, Room A21, National Institute of Standards & Technology, Gaithersburg, MD 20899; (301)975-4109.

Physical Sciences

1087 Metal Hydride Slurries (Licensing Opportunity)

1088 Properties of Methane Developed

1089 Enzyme Work Increases Industry Profits

Testing & Instrumentation

1090 Gravimeters Used Successfully

1091 Dynamic-Range Compression for Infrared Imagery—Photorefractive crystals covering detectors would prevent saturation.

Testing & Instrumentation

1092 Automated Hot-Cell Titration System

1093 Review of Current Methods for Measuring Particulate Matter Including Condensables from Stationary Sources

1094 Long-Wavelength Infrared Detector—Intersubband absorption in coupled quantum wells would enable detection at wavelengths from 10 to 100µm. (Licensing Opportunity)

1095 Making Durable Specimens for Electron Microscopy—Consistent metal-oxide cross sections are prepared quickly.

1096 Measuring Transmission Efficiencies of Mass Spectrometers—Coincidence counts would yield absolute efficiencies.

Other Items of Interest

1030 Choosing Compositions of Electrocatalysts—The best alloys for fuel cells and batteries can be determined from thermodynamical considerations. (Licensing Opportunity)

1055 Chemiluminescent Light Generating

1056 New Material can Help Gauge Sulfur Emissions

1067 Process Developed to Remove Twins in YCBO Crystals

1071 Isothermal Equation of State for Compressed Solids—The same equation with three adjustable parameters applies to different materials.

1076 Thermal Analysis of Reluctant Glass Formers—A thermocouple holds a sample and monitors its temperature during cooling.

1079 Platinized Chloroplast: A New Bioelectronic Material

Department of Energy

Technology Application

Brookhaven National Laboratory

Metal Hydride Slurries

The use of reversible metal hydrides for many diverse applications has received increasing attention over the past few years. The utility of these materials stems from their ability to absorb and desorb large amounts of hydrogen at convenient temperatures and pressures. Existing and proposed applications include hydrogen purification, energy storage, heat pumps, and isotope separation. However, current technology involving such applications requires the contact of hydrogen gas with a dry, immobile bed or aggregate of metal/metal hydride particles. Consequently engineering parameters associated with heat transport and transfer, gas-solids separation, and vessel distortion due to solids expansion and contraction, have imposed severe constraints on system design. Such constraints may be eliminated or substantially reduced by using metal hydride slurries in place of static, dry bed contactors. In this connection it has been discovered that several intermetallic hydride formers such as LaNi5, LaNi4.7Al.3 and TiFe0.7Mn.2 will absorb and desorb hydrogen while suspended in liquid hydrocarbons such as n-octane and n-undecane. The H2 absorption and desorption rates by the suspended solids are rapid and well within the range required for practical applications. The advantages deriving from the liquid like properties of such suspensions relative to conventional dry bed technology can be enumerated as follows:

1) Heat addition or removal is no longer the rate limiting engineering parameter.

2) A slurry can be easily pumped.

3) Gas/solid separation problems are reduced.

4) Problems stemming from bed expansion and contraction are eliminated.

5) Much greater flexibility in system design possible.

6) A very important advantage, which deserves emphasis, is that hydrogen can be readily extracted from mixed gases consisting of volatile hydrocarbon contaminants or other inert gases. This behavior is quite different from that of the dry contact systems where the presence of any contaminant, even helium, will greatly inhibit the uptake of hydrogen because of the buildup of a blanketing, high concentration layer of the inert component at the gas/solid interface.

FOR ADDITIONAL INFORMATION: Dr. William Marcuse, Head, Office of Research and Technology Applications, Bldg. 475-B, Brookhaven National Laboratory, Upton, NY 11973; Commercial (516)282-2103. Refer to BNL/AA-43TN.

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Properties of Methane Developed

The thermophysical properties of methane have been tabulated by NIST for a large range of fluid states based on recently formulated correlations. The use of improved correlations is important economically because methane is the major constituent of natural gas. The tables include: thermodynamic properties at temperatures from 91 to 600 K and pressures less than 100 MPa, viscosity at temperatures from 91 to 400 K and pressures to 55 MPa, and thermal conductivity from 91 to 600 K and pressures less than 100 MPa. Algebraic expressions and associated tables of coefficients are given to permit additional property calculations. A FORTRAN program is listed for the evaluation of methane thermophysical properties using the Schmidt-Wagner equation of state with separate correlations for the viscosity and thermal conductivity.

FOR ADDITIONAL INFORMATION: Copies of Tables for the Thermophysical Properties of Methane (TN 1325) are available from NTIS, Springfield, VA 22616; (703)487-4600.

Department of Energy

Technology Application

Solar Energy Research Institute

Enzyme Work Increases Industry Profits

SERI researchers are at work lowering the expense of industrial enzyme use by producing enzymes that remain active longer under the harsh conditions encountered in industrial reactions.

Today, industry commonly uses enzymes to help break down starch in the production of alcoholic beverages, to degrade cellulose in clarifying fruit juices and modifying fruit and vegetable products, and as protein- and lipid-degrading agents in detergents and meat tenderizers.

Using special chemical reagents, SERI researchers are modifying enzymes by reticulation—the formation of a network of covalent chemical bonds between different portions of the folded peptide chains that make up the molecules of enzymes and other proteins.

The man-made supplementary bonds created by this type of crosslinking produce enzymes with greater physical stability than occurs naturally.

One example of such modification is the enzyme β-glucosidase, which is produced by the fungus *Aspergillus niger* and used to supplement the conversion of cellulose to glucose for fermentation to fuel alcohol. During the past year, researchers in SERI's Applied Biological Sciences Section of the Biotechnology Research Branch have developed crosslinking techniques that increase the lifetime of this enzyme more than 200-fold at the elevated temperature.

Through such efforts in enzyme technology, SERI is helping clients enhance their industrial processes and achieve greater profitability.

Contact: Dr. Karel Grohmann
(303) 231-7252

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Gravimeters Used Successfully

Highly sensitive and portable instruments to measure the acceleration of gravity, developed by the NIST-University of Colorado Joint Institute for Laboratory Astrophysics (JILA), have performed successfully at various sites around the country in field tests by the National Geodetic Survey. The results of this initial year of field testing pave the way for a network of measurements made with these instruments, both in the United States and abroad. They will be used to monitor local variations in gravity, study vertical ground motions for earthquake detection, and assist in the determination of sea level changes.

FOR ADDITIONAL INFORMATION: A paper describing the field test is available from Jo Emery, NIST, Division 104, Boulder, Colo. 80303.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Dynamic-Range Compression for Infrared Imagery

Photorefractive crystals covering detectors would prevent saturation.

The results of experiments suggest that photorefractive crystals can be used to reduce the dynamic range of infrared radiation incident upon a photodetector or array of photodetectors. Such predetection range compression can be useful in infrared-imaging systems because typical scenes contain bright spots (e.g., solar radiation reflected from automobiles) on dark backgrounds, and the bright/dark contrast exceeds the dynamic ranges of photodetectors, causing their output signals to saturate. When fully developed, an effective dynamic-range-compressor plate, film, or coating would reduce the apparent contrast of the scene imaged on the detector plane to within the dynamic range of the detectors (see Figure 1); the original image contrast or intensity data could be recovered subsequently in electronic image processing because the range-compression function and its inverse would be known.

The proposed dynamic-range compressor would be made of photorefractive crystals. The two-wave-mixing process that occurs in such crystals attenuates the radiation passing through them. Because the process is nonlinear, the degree of attenuation is greater at higher intensities. Thus, a compressor plate would darken the bright spots more strongly than it would darken the other portions of an image.

One useful range-compression function is

$$I_{out} = A(I_{in})^X$$

where I_{out} and I_{in} are the input and output intensities, respectively, and A is a constant. For compression, X must be less than 1; as X decreases, the degree of compression increases. This function is approximated by the experimental data of Figure 2, in which the input dynamic range of about 365:1 is changed to output dynamic ranges of about 175:1, 160:1, and 90:1.

This work was done by Li-Jen Cheng and Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**.

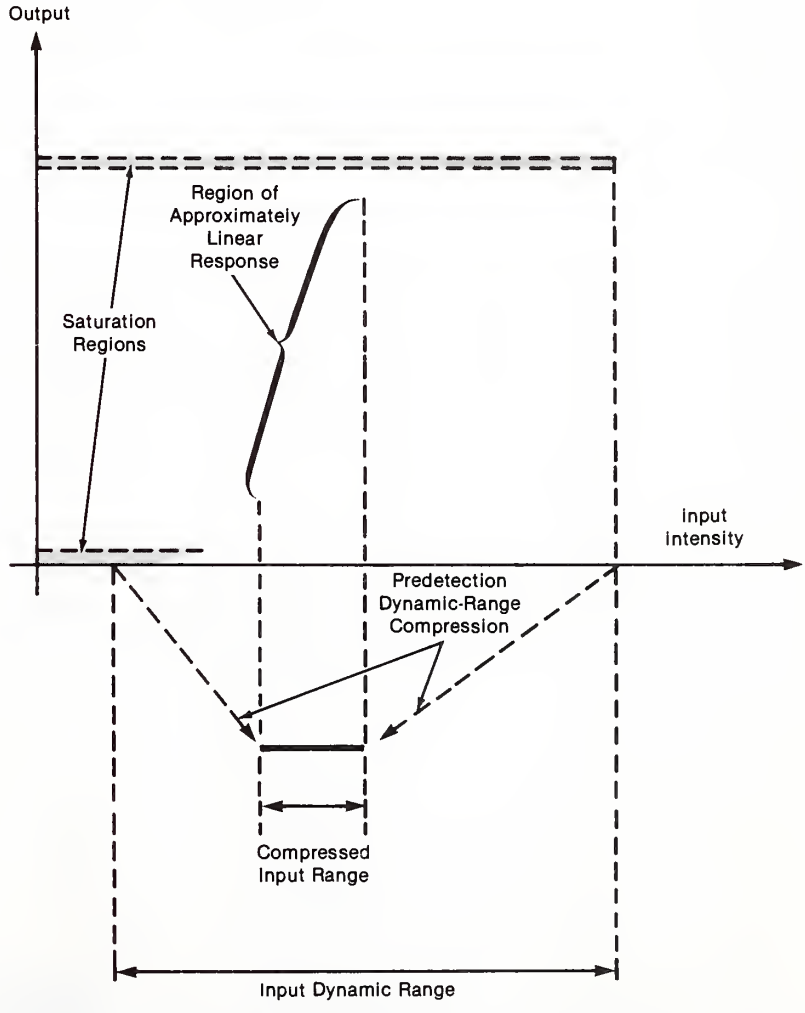


Figure 1. The **Output of a Typical Photodetector** saturates at low and high levels of input intensity. To make full use of the information in an image, it is desirable to compress the dynamic range of the input intensity to within the region of approximately linear response of the detector.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL Laboratory. Refer to NPO-17140/TN.

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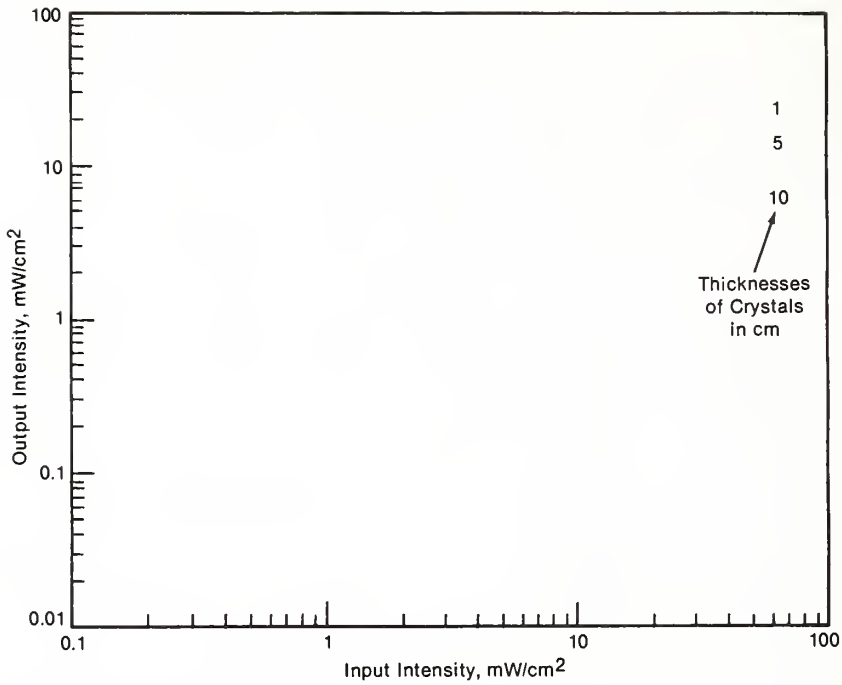

Figure 2. **Dynamic-Range Compression** is exhibited by measurements of attenuation in photorefractive GaAs.

NASA Tech Briefs, June 1989

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Oak Ridge National Laboratories

Automated Hot-Cell Titration System

Operation of a nuclear-fuel-reprocessing plant requires an analytical support laboratory capable of meeting process-control, product-quality, and nuclear-safeguard requirements. Because of the radioactivity accompanying many of the samples, the analytical instruments must be selected, modified, or specifically developed for use in hot cells. Titrimetric procedures have been used successfully in hot cells and are generally immune to radiation-induced bias. The principal disadvantage of titration, which has led to the development of automated titration systems, is that it is generally a time- and manpower-intensive procedure.

An automated titration system has been developed in ORNL's Analytical Chemistry Division specifically for operation in a hot-cell environment (Fig. 1). This system is composed of an in-cell titrant delivery unit, in-cell electronics systems, computer interfaces, a microcomputer, and software. The titrant delivery unit inside the hot cell is linked to the microcomputer in the operator area of the laboratory by means of a signal-distribution box.

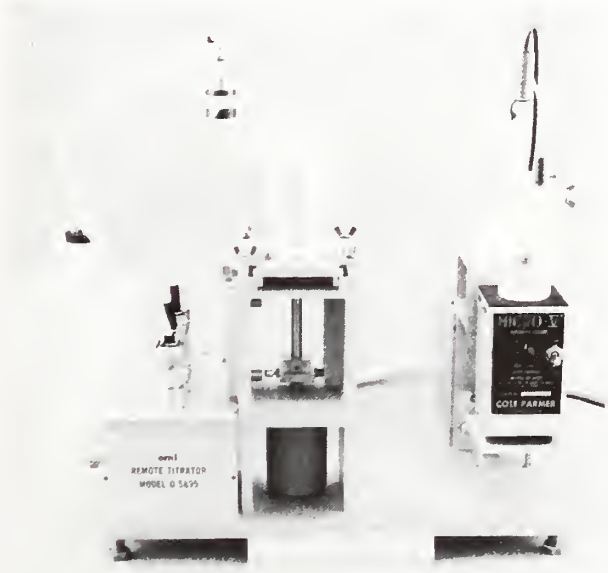

Fig. 1. In-cell system of the ORNL remote titrator.

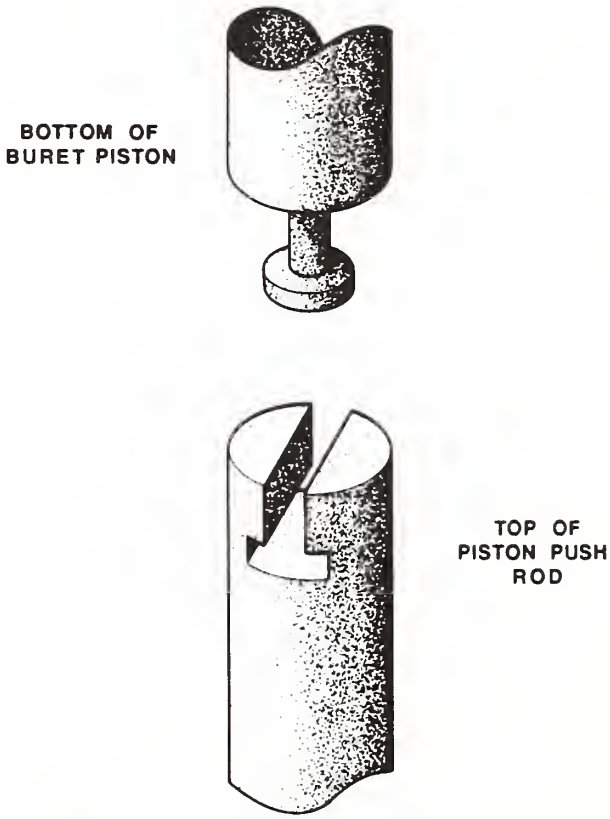

Fig. 2. Push rod-to-piston coupling for titrant delivery unit.

The operating principle of the titrant delivery unit is the piston displacement of liquid. The delivery drive consists of a stepping motor that turns a precision-ground lead screw. Attached to the motion-conversion nut is a permanent magnet that actuates Hall-effect proximity switches to stop the stepping motor at the full and empty positions of the buret. The end of the piston push rod connects to the piston with the coupling system shown in Fig. 2. The orientation of the piston push rod is fixed; the piston is free to rotate. When the push rod is positioned at the buret change position, this coupling system allows the buret to be removed and attached by

sliding it horizontally.The buret is positioned on the delivery unit housing by a spring-loaded locating pin with a hemispherical head and is clamped securely to the delivery unit housing. A three-way solenoid valve mounted on the buret housing is used to control the direction of fluid flow during all movements of the buret piston.

Interchangeable burets having barrels fabricated from precision-bore Pyrex tubing are available with capacities of 5, 10, and 25 mL. The means of the absolute error in delivered volume for these burets are 0.9, 1.1, and 1.8 μL, respectively.

An elevator module is used to position the titration vessel under the electrodes and titrant delivery tubes. It is powered by a reversible ac motor; limit-of-travel signals are generated by Hall-effect proximity sensors, which are actuated by a permanent magnet attached to the rear of the elevator table.

Data indicate that the titrant delivery unit performs its task with high accuracy and precision. The titration system has been used successfully for potentiometric titrations for several years in support of nuclear-fuel-reprocessing R&D activities. Evaluation studies have shown that this system's accuracy and precision are not limited by titrator performance factors but by sample preparation procedures, the equilibrium constant of the titration reaction, and statistical uncertainities associated with the standard titrant.

This system is also capable of performing amperometric titrations. Changing between the potentiometric and amperometric modes of operation involves changing the in-cell transducers, the in-cell electronics, and the titrator control program.

L. N. Klatt, *A Hot-Cell Titration System*, ORNL/TM-10780, Oak Ridge National Laboratory (July 1988).

Additional information:

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Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6257
(815) 574-4192

United States
Environmental Protection
Agency

Atmospheric Research and
Exposure Laboratory
Research Triangle Park NC 27711

Research and Development

EPA

Project Summary

Review of Current Methods for Measuring Particulate Matter Including Condensables from Stationary Sources

The PM_{10} ambient air particulate concentration standard has created a need for updating measurement methods for PM_{10} emissions (nominally 10 μm aerodynamic diameter and smaller) from stationary sources. Condensable emissions can be a significant portion of stack emissions. Further, since these substances primarily condense to particles less than 10 μm in diameter, they form a greater percentage of the PM_{10} fraction than of the total particulate matter emissions. Therefore, the need arises for developing a source test method which includes the condensable component of emissions. A review of possible techniques was conducted to determine current methodology and to make recommendations for research. Research is recommended on two approaches. One is a dilution method which simulates plume formation by mixing stack gases with conditioned ambient air; the other is an adaptation of utilizing the Method 5 back-half catch.

This Project Summary was developed by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Stationary sources contribute to the ambient particulate burden through three distinct mechanisms. Two are normally considered together as the formation of "primary" particulate emissions from sources, and the third is the formation of "secondary" aerosols, such as sulfates formed from SO_2 and organic smogs formed from photochemical processes. Primary emissions are composed of (1) materials that are in particulate form (solid or liquid) in the gas stream before and after discharge to the atmosphere and (2) materials that are in the vapor phase before discharge but that rapidly condense to the particulate form when they are discharged into and cooled by mixing with ambient air.

Because condensation takes place preferentially on small particles, condensable matter is concentrated primarily in the PM_{10} fraction (particulate matter less than 10 μm in diameter) of source emissions. Since the basis of the standard for ambient air particulate concentrations has been changed from total particulate concentration to PM_{10} concentration, quantitative data on condensable emissions rates will be needed to set up State Implementation Plans for compliance with ambient air PM_{10} standards. However, current methods for particulate emissions measurement usually exclude the condensables fraction.

Efforts are now being made to develop a reference method to quantify the condensables fraction separately from measurements of the particulate portion of primary emissions from stationary sources. In addition, a working definition for stationary sources condensable emissions must be established to develop a reference method. A review of possible techniques was conducted from which recommendations are made for the optimum approach for development of routine field sampling procedures for measuring condensable emissions.

Approaches for Measuring Condensable Matter

To explore the possible options for measuring condensable matter, a working definition of condensable matter is needed. In particular, the quantity of condensable matter that is present can vary because equilibrium vapor pressures and condensation and evaporation rates vary significantly with changes in temperature and other conditions including concentrations. Consequently, the partitioning between the vapor and particulate phases of condensable matter will exhibit seasonal variations. From a regulatory point of view, however, the reference method(s) used for measuring condensable matter should provide results that are not dependent on local temperatures. Thus some standard temperature for sample collection is needed, such as 0, 5, 20, or 25°C. Whatever

temperature is designated to be standard, the operational definition of condensable emissions should be that material collected by the selected reference method(s). This type of definition is now used for particulate matter collected by Method 5.

Adaptations of Method 5

In considering the back-half catch as described in Method 5 for further development as a vehicle for collecting condensable matter, certain problem areas must be addressed. A protocol must be devised for carrying out the evaporative process to remove the large volumes of water from the impinger solutions while reducing to acceptable levels any losses of the condensable materials that are to be measured. Because impingers used in conjunction with Method 5 result in vigorous contact between sample gases and impinger solutions, the potential for reactions with gases that could cause positive measurement biases must be eliminated or minimized. Also, impingers may enhance uptake of gases when sampling for condensable materials with Method 5. Research should be performed to determine if these effects occur at a significant level and to eliminate or minimize them if necessary. Use of a coil-type condenser may reduce these effects. A filter downstream of the impinger/condenser could be used, if necessary, to ensure that no aerosolized portion of the condensate escapes with the spent sample gas.

Working Definition of Condensables

Because the split of any condensable component of emissions from a source between the vapor and condensed phases depends on temperature (and for some compounds, the amount of dilution that has taken place and background concentrations of the material), it is recommended that condensable emissions be defined as the material measured by the sampling train selected by EPA for collecting condensable matter. Primary emissions that include condensable matter would be defined by the catch of the sampling train, inclusive of the nozzle through the filter.

Suggested Dilution Sampling Method

The use of low mixing rates to preserve, insofar as possible, the detailed size distribution characteristics that would develop in the actual plume was not considered to be an important factor by most of the experts who provided advice. By foregoing any attempt to preserve the detailed particle size distribution of the final aerosol, rapid mixing of the incoming sample stream and the dilution air can be used. This permits the design of a compact diluter and keeps the weight and size of the device at a minimum.

Conditioning recommended for the dilution air includes filtration to remove background particulate matter and drying to a dewpoint of 35°F (1.5°C), with a final temperature of 68°F (20°C). The low dewpoint and moderately high dilution ratio should prevent problems of moisture condensation for most flue gases that might be encountered.

Because the sample flow is only a small part of the total flow, measurement of the sample flow at the exhaust end of the system, as in Method 5, is not possible in the recommended setup. Instead, a flow-metering element may be installed upstream of the sample inlet to the diluter. A venturi-type flow meter is recommended, but other types might be used.

Conclusions and Recommendations

The dilution method appears to be one of two suitable approaches for research and development for measuring total primary emissions including condensable matter from stationary sources. This approach forms condensed particulate matter by the same physical mechanism that occurs in actual plumes. Construction of a system with traversing capability that is suitable for field use appears feasible; consequently, this approach is recommended for development. The other suitable method is the impinger/condenser approach. This approach requires the least investment in terms of methods development, operator training, and capital equipment costs (because existing equipment may be adequate). Research and coincidental testing should be designed to reveal the relative merits of the dilution and impinger/condenser approaches.

Joseph D. McCain and Ashley D. Williamson are with the Southern Research Institute, Birmingham, AL 35255-5305.
***Thomas E. Ward** is the EPA Project Officer (see below).*
The complete report, entitled "A Review of Current Methods for Measuring Particulate Matter Including Condensables from Stationary Sources," (Order No. PB 89-169 973/AS, Cost: $13.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Atmospheric Research and Exposure Assessment Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Long-Wavelength Infrared Detector

Intersubband absorption in coupled quantum wells would enable detection at wavelengths from 10 to 100 μm.

A proposed device would detect infrared photons of 10- to 100-μm wavelength by intersubband absorption in coupled quantum wells. Such a device would be made of $Al_xGa_{1-x}As$/GaAs or other semiconductor material, even though the material may not have any intrinsic absorption in the desired range of wavelengths.

Recently, quantum-well devices made of layers of $Al_xGa_{1-x}As$ and GaAs have been demonstrated to detect radiation at wavelengths of 8 to 11 μm. The absorption of a photon in such a device corresponds to the transition of an electron between the ground and first excited state of a quantum well formed by the discontinuity in the energy of the conduction band between a GaAs well and an $Al_xGa_{1-x}As$ barrier. The photoexcited charge carriers then tunnel out of the well and are collected with the aid of an applied electric field.

The proposed device is based on the splitting of the energy level that occurs when two quantum wells are placed so close together that the wave functions of the quantized energy levels overlap. The detector absorbs photons, the energy of which equals the difference in energy between two levels that result from the split. Because the degree of overlap of the wave functions and, therefore, the magnitude of the split can be varied by varying the width of the barrier between the two coupled wells, such a detector can, in principle, be designed to operate at any desired wavelength.

Operation at wavelengths from 10 to 100 μm requires splits of 12 to 120 meV. A split of 25 meV (corresponding to a wavelength of 50 μm) could be obtained by use of GaAs wells 70 Å thick, with $Al_{0.06}Ga_{0.94}As$ barriers, including a 14-Å-thick barrier between the wells. This approach to design could be used in other combinations of materials that exhibit quantum size effects and is not restricted to the $Al_xGa_{1-x}As$ system.

The restrictions on the design parameters of quantum wells of the proposed device are less severe than those of single-well devices. However, energy levels near the tops of the wells are still necessary so that the photoexcited carriers can tunnel out. Additional flexibility in design can be obtained by use of wells of different widths and asymmetric wells formed by barriers of different heights.

This work was done by Richard P. Vasquez of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 19 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Residence Office-JPL. Refer to NPO-17543/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Making Durable Specimens for Electron Microscopy

Consistent metal-oxide cross sections are prepared quickly.

High-quality specimens of metal-oxide cross sections transparent to electrons are necessary to perform some of the more sophisticated studies involving transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM). A major problem in the preparation of specimens is obtaining durable specimens in a simple and consistent fashion. A new technique can be used to prepare 3-mm-diameter specimens of cross sections of oxides of alloys intended for use at temperatures greater than approximately 600 °C (see figure).

The alloy of interest is cut into bars approximately 1.5 mm by 0.75 mm by 10 mm. Only one of the large faces of each bar need be prepared for oxidation treatments. The bars are oxidized at the appropriate experimental conditions. After the bars are cooled, a thin coat of silver paint is applied to the prepared surface of each bar. The painted surfaces are placed and held together until the paint dries. This provides enough strength for handling of the specimen-bar sandwich.

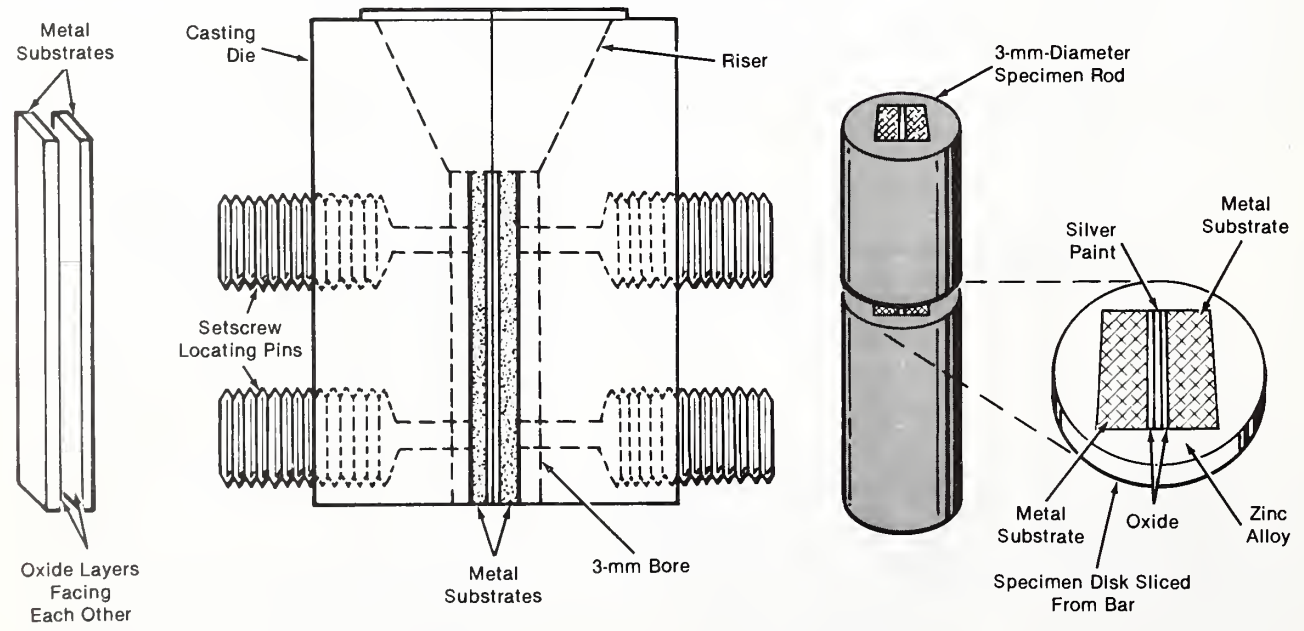
The sandwich is then placed in a specially-designed stainless-steel mold and held in place with setscrew pins. The purpose of the mold is to hold the sandwich in place inside a 3-mm-diameter bore, into which a molten alloy is injected. After the sandwich is aligned in the mold, a chunk of Zn(4 atomic percent)/Al(1 atomic percent)/Cu alloy is placed in the riser portion of the mold. This alloy was chosen because of its low melting temperature (415 °C), sufficient strength, and high coefficient of thermal expansion.

The entire mold is heated quickly with an oxyacetylene torch until the alloy is molten. A glass tube connected to a rubber bulb is placed over the riser and in contact with the mold. A blast of air causes the molten alloy to flow around and encapsulate the specimen-bar sandwich. After removal from the mold, the resulting 3-mm specimen bar is sliced into TEM specimens by use of a slow diamond saw. Finally, the specimens are polished, dimpled, and ion-thinned.

The primary advantage of this technique is that durable specimens can be prepared consistently in a very short time. In addition, epoxy resins are not used, and organic solvents can be used to clean the specimens. Yet another advantage is that two different experimental conditions can be incorporated into one specimen.

One of the disavantages of this technique is that specimens of materials that would be affected by the high casting temperature are not suitable. Furthermore, during the ion-thinning process, the zinc alloy is often sputter-deposited on the area of interest, requiring subtraction of additional background signals from quantitative-chemical-analysis spectra.

This work was done by Joseph Doychak of Sverdrup Technology Inc. for **Lewis Research Center.** *LEW-14755/TN*



The **New Process** makes TEM/STEM cross sections of metal/oxide interfaces. After the specimen bars have been oxidized, they are placed in the specially designed mold. Following encapsulation in the zinc alloy, the 3-mm-diameter specimen bar is sliced into disks suitable for further preparation steps.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Measuring Transmission Efficiencies of Mass Spectrometers

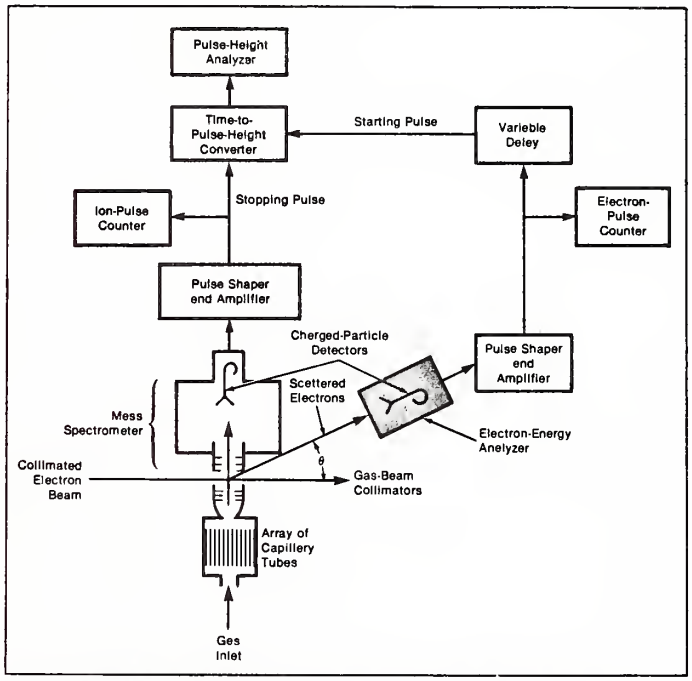
Coincidence counts would yield absolute efficiencies.

A proposed system would measure the mass-dependent transmission efficiencies of mass spectrometers, using coincidence-counting techniques reminiscent of those used for many years in the calibration of detectors for subatomic particles. When fully developed, the system should be compact, portable, and used routinely to calibrate mass spectrometers.

The conceptual system is connected to the inlet and to the output circuit of the mass spectrometer (see figure). A gas (e.g., H_2, D_2, He, Ne, N_2, O_2, Ar, or CO_2) is passed through an array of capillary tubes, then through a series of apertures to form a well-collimated, well-defined beam of molecules. This beam is crossed by a beam of electrons with kinetic energies greater than the ionization potential of the molecules and with an energy spread less than 300 mV. Some of the collisions between electrons and molecules produce singly ionized molecules that travel toward the entrance aperture of the mass spectrometer, and scattered electrons, the kinetic energies of which are diminished by the amounts lost in production of the ions.

The electrons scattered at some arbitrarily chosen angle θ are analyzed in energy and detected by a multichannel amplifying plate or other suitable charged-particle detector. Each detected electron gives rise to an electrical pulse that is shaped, amplified, and sent to a pulse counter: it is assumed that each pulse at a specified scattered-electron energy corresponds to an ion that has begun to travel toward the entrance of the mass spectrometer. The electron-detector output is also fed through a variable-delay unit to start a time-to-pulse-height converter.

Another charged-particle detector, another pulse shaper, and another amplifier form a pulse for each ion that arrives at the output end of the mass spectrometer. Each ion pulse serves as the stopping pulse for the time-to-pulse-height converter. Between the starting and stopping pulses, there is a time correlation for those detected ions that were produced by detected electrons. For other detected ions and electrons, there is no time correlation. Thus, the output of the time-to-pulse-height converter includes uncorrelated pulses spread over a wide range of time intervals, plus correlated pulses spread over a fixed time interval, as shown in the output of a pulse-height analyzer.



Coincidences Between Detected Ions and the Electrons That Produced Them would be counted during the operation of a mass spectrometer. Under certain assumptions regarding the inelastic scattering of electrons, the electron/ion-coincidence count is a direct measure of the transmission efficiency of the spectrometer.

The transmission efficiency of the mass spectrometer is taken to be the ratio of the number of time-correlated pulses to the number of electron pulses. The measurement can be repeated for each of the various gases to obtain the transmission efficiency for the molecular mass of each.

This work was done by Santosh K. Srivastava of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Transportation & Components

1097 Grid Construction for Computational Fluid Dynamics

1098 Airplane-Acceleration Display for Low-Gravity Research—A bar-graph display facilities precise control of trajectories.

NAVY
Domestic Technology Transfer Fact Sheet

Grid Construction for Computational Fluid Dynamics

In order to minimize acquisition costs while maximizing the effectiveness of the Navy's existing and proposed ships, scientists and engineers are developing new designs using advanced supercomputers. For a number of years, the David Taylor Research Center (DTRC) has been a leader in the areas of fluid mechanics, numerical analysis, grid generation, and computational fluid dynamics (CFD). Leadership in these disciplines is now paying dividends in the form of improved vessels that can be brought to the fleet more quickly and economically than ever before. Typically, new designs are first analyzed numerically using CFD techniques so that only the most promising ones need be moved on to the more expensive model-testing phase.

The first step in obtaining an accurate numerical model for a ship hydrodynamics problem is often the construction of a computational grid on the body surface and in the fluid region, which is suitable for the solution of the mathematical equations describing the flow field. Researchers at DTRC have developed methods and computer programs that can produce grid systems for either two- or three-dimensional problems. Both INMESH (2D) and NUGGET (3D) are general-purpose programs, which use a multiblock decomposition of the fluid region to generate meshes for arbitrary geometries. This numerical grid generation procedure yields a

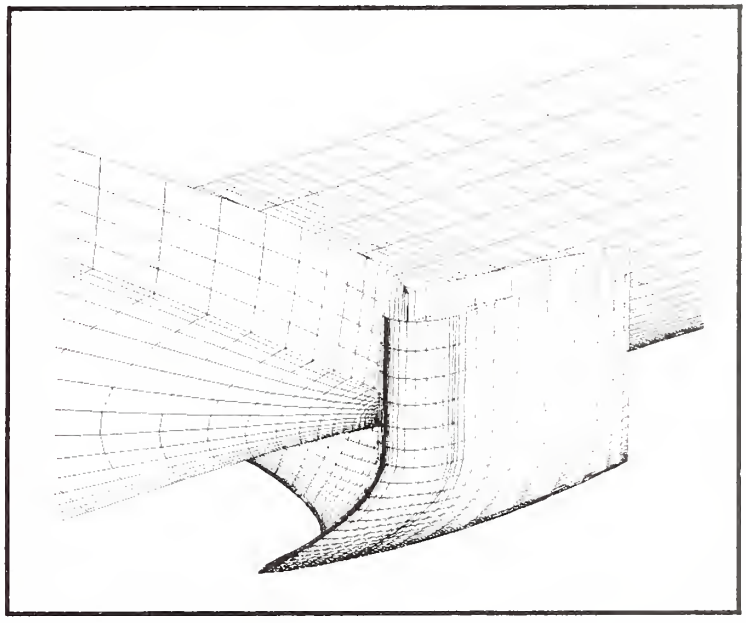

Figure 1. An appendage with fillet*

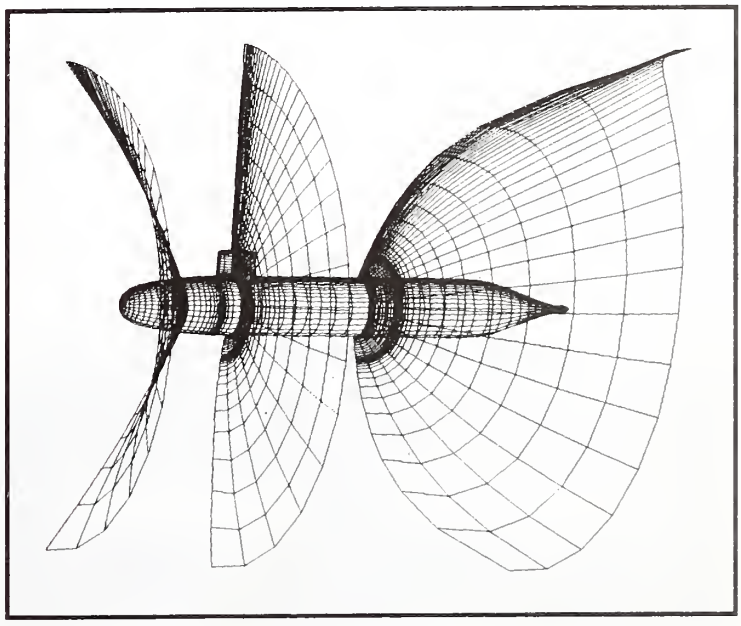

Figure 2. A hull with sail*

*Both three-dimensional grids were produced by NUGGET even though the geometries are quite different.

"boundary-fitted" or "surface-oriented" coordinate system for complex domains in which the bounding surfaces are also coordinate surfaces. As a result, no interpolation is necessary at these boundaries, leading to a more accurate numerical representation of the boundary conditions. The ability to easily handle problems with moving or deformable boundaries, such as a free surface, is another strength of this method, since any time the grid system is recomputed, it automatically adapts to the changes in the geometry of the fluid region.

For Additional Information:

Backup material on this effort is available from:

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Refer to 140603/TN

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Airplane-Acceleration Display for Low-Gravity Research

A bar-graph display facilitates precise control of trajectories.

An acceleration display for an airplane helps the pilot to fly trajectories that produce the effect of zero gravity or fractions of Earth gravity (g) within the airplane. With the help of the display, the pilot can adhere to a predetermined fraction of g, with minimal lateral acceleration.

Developed for a Learjet used for microgravity research, the display consists of light-emitting-diode (LED) bar graphs (see figure). A pitch-axis bias switch lets the pilot select one of nine settings for the zero reference of the display so that any of the following trajectories can be flown: 0 g, $\frac{1}{20}$ g, $\frac{1}{10}$ g, $\frac{1}{6}$ g (Lunar gravity), $\frac{1}{5}$ g, $\frac{1}{4}$ g, $\frac{1}{3}$ g (Martian gravity), $\frac{1}{2}$ g, and $\frac{3}{4}$ g. The accelerations can be sustained within 0.01 g for 5 s, 0.02 g for 7 s, and 0.04 g for 20 s.

Three LED bar displays present acceleration in the x (thrust), y (lateral), and z (pitch) axes. The pitch and lateral displays are located in front of the pilot, who controls the yoke and rudder. The thrust display is located in front of the copilot, who controls the throttles.

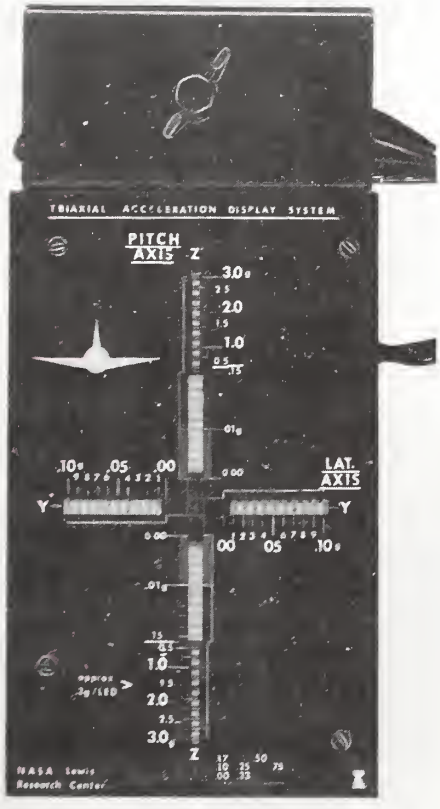
In comparison with the usual needle displays, the LED bar-graph displays take up less panel space and are easier to align with the axes they represent. They have no moving parts and are not subject to parallax. However, they are not legible in direct Sunlight and have resolution limited by the finite sizes of the individual LED's.

The overall display system includes an accelerometer block, a power-supply-and-interface box, the thrust-axis display, and the pitch-and-lateral-axes display. The accelerometer block includes three servoaccelerometers orthogonally mounted on an adjustable triaxial base that allows fine alignment of the accelerometers with respect to the airplane. The accelerometer block and the power-supply-and-interface box are located near the center of gravity of the airplane in the luggage area.

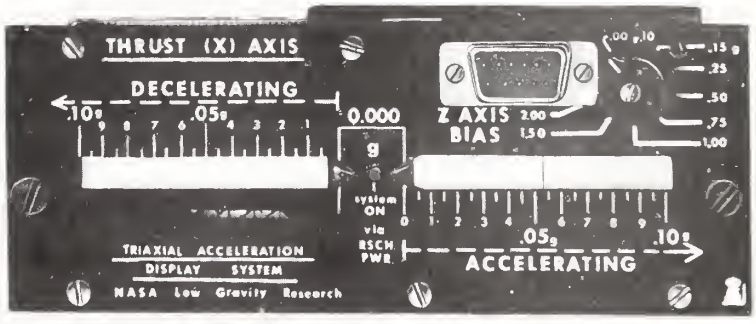
The pitch-axis bar graph has two regions. The innermost LED's (10 positive and 10 negative) have a high-resolution logarithmic scale. The outermost LED's (10 positive and 10 negative) have a low-resolution linear scale. The inner LED's are set to correspond to a range of 0.06 g and the outer stacks to a range of 3 g. The inner LED's are driven by comparators with logarithmic increments to provide finer resolution about zero than would otherwise be possible with a linear scale.

This work was done by Marc G. Millis of **Lewis Reserach Center**. *Further information may be found in NASA TM-87358 [N87-18801/NSP], Price Code: A02 "Acceleration Display System for Aircraft Zero-Gravity Research."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14650/TN



PILOT'S SIDE



COPILOT'S SIDE

The **Pilot, Who Controls Pitch and Yaw,** views the display of pitch and lateral accelerations. The copilot, who controls the throttles, views the thrust-acceleration display.

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